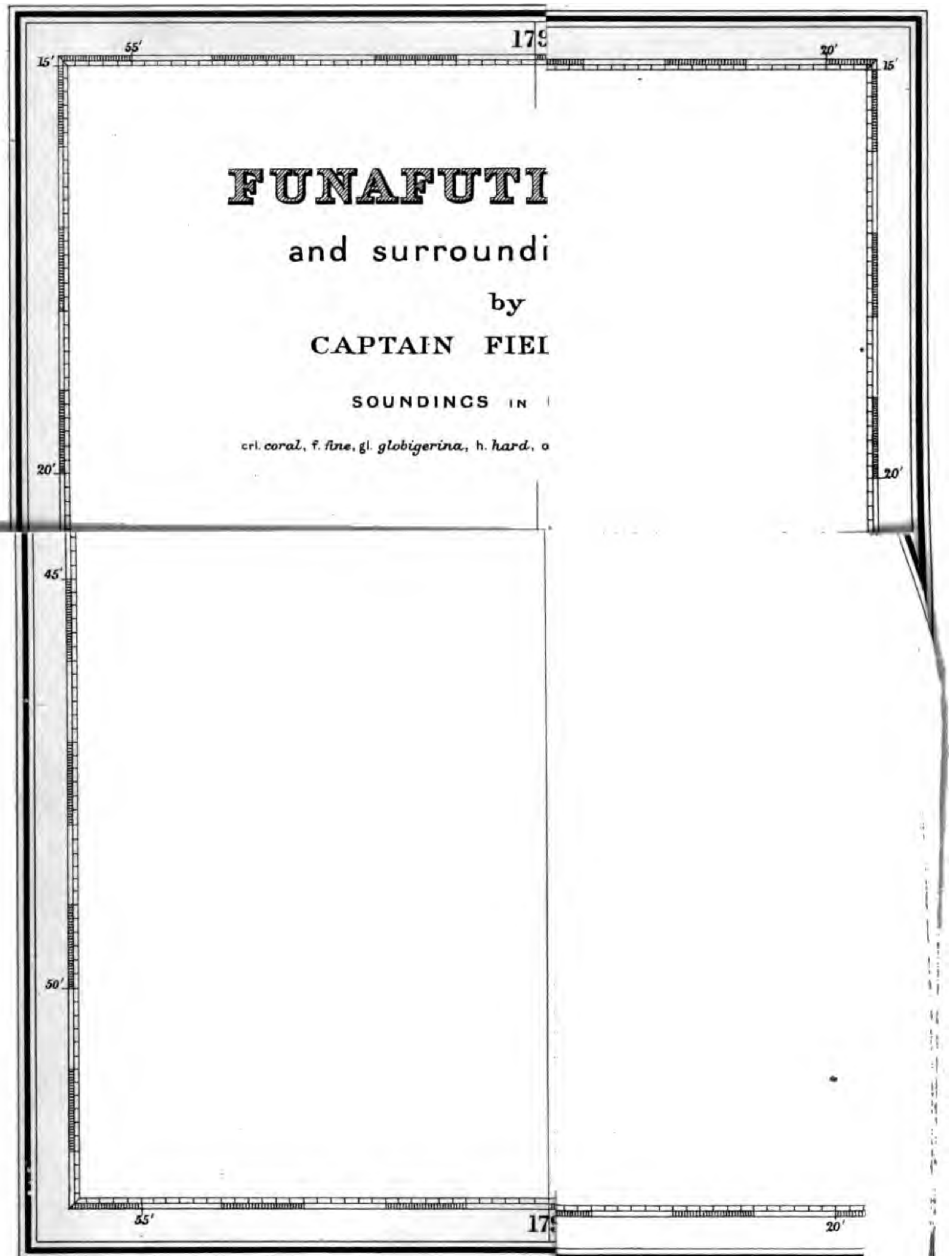
J. G. Cranmer



FUNAFUTI
and surroundi
by
CAPTAIN FIEL
SOUNDINGS IN
crl. coral, f. fine, gl. globigerina, h. hard, o
17
55'
20'
15'
20'
45'
50'
55'
17
20'
Malby &

Cat

J. C. [illegible]
from the Royal Society, London,
at the request of Prof. Judd.
[illegible]

THE ATOLL OF FUNAFUTI.

BORINGS INTO A CORAL REEF AND THE RESULTS.

BEING THE

REPORT OF THE CORAL REEF COMMITTEE

OF THE

ROYAL SOCIETY,

VIZ. :—

ARMSTRONG, PROFESSOR H. E., F.R.S.
BLANFORD, DR. W. T., C.I.E., F.R.S.
BONNEY, PROFESSOR T. G., F.R.S., Chairman.
CROOKES, SIR W., F.R.S.
DARWIN, FRANCIS, F.R.S.
EVANS, SIR J., K.C.B., F.R.S.
GEIKIE, SIR A., F.R.S.
HINDE, DR. G. J., F.R.S.
JUDD, PROFESSOR J. W., C.B., F.R.S.
LANKESTER, PROFESSOR E. R., F.R.S.
LAPWORTH, PROFESSOR C., F.R.S.
MURRAY, SIR J., K.C.B., F.R.S.
SOLLAS, PROFESSOR W. J., F.R.S.
SORBY, DR. H. C., F.R.S.
TEALL, J. J. H., F.R.S.
WHARTON, ADMIRAL SIR W. J. L., K.C.B., F.R.S.
WOLFE BARRY, SIR J., K.C.B., F.R.S.

ACCESSORY MEMBERS:—

FIELD, CAPTAIN A. M.
WATTS, PROFESSOR W. W.

PUBLISHED BY
THE ROYAL SOCIETY OF LONDON.

SOLD BY HARRISON AND SONS, ST. MARTIN'S LANE.

1904.

3/-

CONTENTS.

ILLUSTRATIONS.

CUTS IN TEXT.

PREFACE.

By Professor T. G. Bonney, D.Sc., LL.D., F.R.S., Chairman of the Committee.

The project for examining the structure of an atoll by a deep boring, as recorded in this volume, began to take a definite form rather more than ten years ago in a correspondence on the subject between Professor Sollas, now of Oxford, and Professor Anderson Stuart, of the University of Sydney. The latter, though it lay beyond his special sphere of work, greeted the idea with enthusiasm, and by his good offices with the Government of New South Wales obtained a promise of the loan of a diamond-drill and of other facilities, without which the expenses of the undertaking would have been prohibitive. The first definite step in this country was made at the meeting of the British Association, held at Nottingham, in September, 1893. On that occasion Professor Sollas opened a discussion in Section C (Geology) on "Coral Reefs, Fossil and Recent." Its result was to strengthen the conviction that the origin and history of a coral reef must remain uncertain until the experiment so earnestly desired by the late Charles Darwin himself* had been made, and cores brought up for examination from a boring, which had been carried down to a depth of at least 600 feet. So formidable, however, did the difficulties in this undertaking appear, that, but for the indomitable energy of Professor Sollas it might still be among the things hoped for, and to his initiative and urgency we are largely indebted for the appointment of a Committee before the close of that meeting, to "consider a project for investigating the Structure of a Coral Reef by Boring and Sounding." It consisted of the following: *Chairman*, Professor T. G. Bonney; *Secretary*, Professor W. J. Sollas; *Other Members*, Sir Archibald Geikie, Professors A. H. Green (deceased), J. W. Judd, C. Lapworth, A. C. Haddon, Boyd Dawkins, G. H. Darwin and Anderson Stuart, Captain (now Admiral Sir) W. J. L. Wharton, Dr. (now Sir) J. Murray, Drs. H. Hicks (deceased), and H. B. Guppy, Messrs. F. Darwin, H. O. Forbes, G. C. Bourne, S. Hickson, A. R. Binnie, and J. W. Gregory, and Hon. P. Fawcett. At the Oxford Meeting in the following year this Committee presented an interim report, and was reappointed with a grant of £10 for preliminary expenses, and the addition of the following names: Drs. W. T. Blanford and (now Sir) C. Le Neve Foster, and Mr. J. C. Hawkshaw. After consideration of the relative advantages of the northern Maldives and Funafuti, in the light of evidence kindly supplied by Captain W. J. L. Wharton, Hydrographer to the Admiralty, and by Professor Anderson Stuart, as the result of inquiries made by him at Sydney, the Committee decided

* 'Life and Letters,' vol. 3, p. 184.

in favour of the latter, and reported at the Ipswich Meeting in 1895 that it had applied to the Royal Society for an allocation of £500 from the Government Grant, and that this Society, as a preliminary to discussing the application, was making certain inquiries from the Admiralty, an answer to which had not yet arrived. The Committee accordingly asked to be reappointed, with a renewal of last year's grant, which, as it had not been required, still remained unexpended, and their requests were conceded. At the Liverpool Meeting, in September 1896, the Committee briefly reported the steps which had been taken by the Royal Society, the result of which, as will be seen, was the Expedition headed by Professor SOLLAS, and that, as they were informed by a message just received from him, his second attempt at making a deep boring had been hardly more successful than the first. The Committee also suggested that as the cost of the undertaking was almost certain to exceed the £800 granted by the Royal Society, the Association should augment the funds by a liberal contribution.

The Committee was accordingly reappointed, and a grant made of £40. As the anticipated need of money had not arisen, the Committee did not draw this grant, and reported the fact at the Toronto Meeting in 1897, urging at the same time that as another Expedition had been already sent out from Sydney, the unused grant should form a subscription towards its expense. This was done and the Committee reappointed for another year. At the Bristol Meeting in 1898, the Committee came to an end by reporting that Professor DAVID'S Expedition had been successful, and that the contribution had been paid over to him.

A brief outline must now be given of the part taken by the Royal Society, after the undertaking had been brought before them formally by the recommendation of the Government Grant Committee, that, prior to granting the above-named sum of £500, the Officers and Council of the Royal Society should be requested to apply to the Admiralty for the services of a surveying vessel in 1896 for the purposes of that research. It had also been stated to the Committee that the Government of New South Wales was prepared to assist the undertaking by a free loan of a diamond-boring apparatus.

The Council after consideration of the reports laid before it, passed the following resolution (see 'Minutes,' October 31, 1895).

Professor BONNEY having, in reference to the Expedition for boring a Coral Reef (see 'Minutes,' October 17), reported a resolution of a Committee appointed by the British Association, requesting the Royal Society to appoint a Committee who would undertake the supervision of arrangements for the investigation, and having further reported that the estimate of expenses upon inquiry and consideration had been reduced to £800.

Resolved: That the following gentlemen be a Committee to superintend the arrangements for the Expedition to Bore a Coral Reef as proposed in Application D 22 (1895):—Mr. WOLFE BARRY, Professor BONNEY, Mr. CROOKES, Sir A. GEIKIE, Mr. F. DARWIN, Professor JUDD, Dr. J. MURRAY, Professor SOLLAS, Mr. WATTS, and Admiral WHARTON; Professor BONNEY to be Chairman, and Professor SOLLAS and Mr. WATTS to be Secretaries.

It was further Resolved: That the Treasurer be authorised to apply to the Government Grant Committee for an assignment of £800 from the Reserve Fund, in aid of the Expedition.

The Council, as stated in their 'Minutes' of October 17, had already received from the Admiralty a conditional promise of assistance from H.M.S. "Penguin," in conveying the party and machinery for the research, and at their Meeting of November 7, added the President and Officers to the Coral Reef Committee. At subsequent dates, in compliance with recommendations from that Committee, Captain A. M. FIELD of H.M.S. "Penguin," and Professors EDGEWORTH DAVID and ANDERSON STUART were appointed as members.

By the end of the year, the outlines of an Expedition to Funafuti, an island in the Ellice Group on lat. 8° 30′ 45″ S., long. 179° 13′ 30″ E. were determined, and Professor SOLLAS was requested at a Meeting held on December 17, to take charge of the Expedition as Naturalist; at another Meeting (January 27, 1896), the Committee accepted the offer of Mr. STANLEY GARDINER to accompany it at his own expense as second Naturalist, provided he were at liberty to select his own subjects for investigation.

Passing over the correspondence and arrangements in regard to machinery and other matters between the Committee in London and Professors ANDERSON STUART and EDGEWORTH DAVID, their representatives in Australia, as not belonging to the scientific work of the Expedition, we come to the instructions drawn up by the Committee for the guidance of Professor SOLLAS, as leader of the Expedition, and sanctioned at a meeting held March 4, 1896. They run as follows:—

The Committee wish it to be understood that the primary object of the Expedition is to investigate, by means of a boring, the depth and structure of a coral reef, and that all other work undertaken in furtherance of natural knowledge must be considered as secondary to this object. Professor SOLLAS, however, should endeavour to arrange with Mr. GARDINER, and any other volunteer who may accompany the expedition for such systematic observations as may be possible on the natural history of Funafuti, the neighbouring sea, or the part of the ocean traversed during the voyage. Magnetic observations on the island, it is understood, will be undertaken by the officers of the "Penguin," and Captain FIELD has also been directed to note the currents and temperature in the lagoon and to secure samples of water from it at different depths and from the sea outside. Inland and shore collecting should be undertaken so far as due attention to the main object of the Expedition permits, and dredgings should be made in the lagoon if possible.

Mr. S. GARDINER will accompany the Expedition as a volunteer with the sanction of the Committee paying his own expenses and selecting his own subjects for study, with the general understanding that he will lend such aid as may be in his power to Professor SOLLAS in effecting the main object of the Expedition, and will co-operate with him in making the study of the reef, its fauna, flora, and vicinity in general, as complete as possible. Professor T. EDGEWORTH DAVID or some other scientific man from Sydney, may also join the Expedition on like terms, provided room can be found for him by Captain FIELD on board.

The Committee considers Professor SOLLAS to be in charge of the undertaking and empowers him to decide in all cases of primary importance. He is also empowered, in the event of Funafuti speedliy proving to be an unsuitable place for the boring, to transfer the operation (subject to the consent of Captain FIELD) to some other convenient locality. If in the course of the boring, a rock other than coral limestone be struck, Professor SOLLAS is empowered to use his discretion and to continue the boring if he thinks it desirable.

He is also empowered, if rapid progress be made, to carry the boring to a depth of 1,000 feet, but he must bear in mind that the sum placed at the disposal of the Committee is £800, and that the total and

final expenditure, allowing a sum of about £100 for loss on diamonds in the progress of the work, must not exceed the former sum. Injuries to the machinery have to be made good at the expense of the Committee; every care therefore should be taken to preserve their rods and other tools in good condition, by the use of Brunswick black, tallow, &c. Also payment should be offered to the Department of Mines at Sydney for stores used up on the Expedition.

Professor SOLLAS, on arrival at Sydney, is to make the necessary arrangements with the Department of Mines, with the foremen furnished by them, and for the purchase of stores for the use of the Expedition. It is left to Professor SOLLAS, in consultation with Professor DAVID and Captain FIELD, to decide as to the quantity of rods, tubes, and other subsidiary articles that are to be carried with the apparatus. In the event of his not returning *viâ* Sydney, he must take care to deliver all the apparatus lent by the Department of Mines to a responsible person for conveyance back to Sydney and to obtain a satisfactory receipt for them, also to arrange for paying wages to all workmen employed, and any debts incurred in carrying out the investigation; in other words to wind up all the business connected with the Expedition, in that part of the world, either in person or through a responsible agent, so as to secure the Committee against unforeseen claims for wages, purchases, or damages.

Professor SOLLAS is to make arrangements for the safe transmission of the diamonds back to England or for the sale of them in Sydney if this can be advantageously done. Professor SOLLAS is expected to keep an account of all expenditure for the purpose of the investigation and as far as possible to obtain vouchers. This will be necessary in order that, among other purposes, Professor SOLLAS may be able to judge when the approaching exhaustion of the funds makes it necessary to conclude the investigation.

The Committee expect Professor SOLLAS personally to superintend the withdrawal of the cores, to see them both so labelled that identification of each specimen is secured, and safely packed for transmission, by such conveyance as he shall arrange. Of these cores and of such other specimens as may be collected by the Expedition (not referring to specimens collected by the volunteers in their private capacity) the first set will be ultimately presented to the British Museum, the second to the Ministry of Mines at Sydney. It is left to the discretion of Professor SOLLAS to make the division on the spot and to send the second set of specimens or such part as will not be wanted for study in England, direct to Sydney. But all specimens which are needed for working out the results of the Expedition will be retained by the Committee until this has been done. The consent of the Committee must be obtained by any member of the Expedition before publishing scientific details of the investigation.

The Committee hope that in the event of illness or accident Professor SOLLAS will endeavour to arrange for the continuance of the investigation.

(Signed) T. G. BONNEY, *Chairman.*

The story of this Expedition is told by Professor SOLLAS in Section I, and on November 13, 1896, he presented to the Coral Reef Committee a report on its principal events, the causes of the failure to attain a greater depth than 100 feet, and its general scientific results, after which the following resolution was unanimously passed:—

That the Committee are of opinion that Professor SOLLAS in abandoning, under the conditions he has reported, further attempts to prosecute the boring, came to a very proper conclusion, and that the thanks of the Committee are due to him for the manner in which he conducted the Expedition under his charge.

Instructions were given at the same time for presentation of a preliminary report to the Royal Society* and for the sale of the carbonadoes which had not been

* See 'Proceedings,' vol. 60, p. 502.

expended in the boring. This transaction added considerably to the cost of the undertaking, for the purchase had to be made within very narrow limits of time, when the price of carbonadoes was quite exceptionally high, and at the time of the sale it had fallen greatly. The Committee bought $93\frac{1}{8}$ carats at £6 5*s.* per carat, the residue was sold in April, 1897, at only £3 15*s.* per carat, so that allowing for loss in usage (which had been from the first estimated as about £100) and the agent's commission, only £284 10*s.* was received against £582 0*s.* 7*d.* expended.

The following balance sheet was presented to and accepted by the Committee at a Meeting held on June 29, 1897, from which it will be seen that the total cost of the Expedition amounted to £1,064 3*s.* 10*d.*

BALANCE SHEET.

Receipts.	£	*s.*	*d.*	£.	*s.*	*d.*	Expenditure.	£	*s.*	*d.*
Grants :—							Expenditure	1,341	11	7
Government Grant				250	0	0	Loan repaid, Royal Society	550	0	0
" "				800	0	0	" " W. W. Watts	50	0	0
Council Fund				20	0	0	British Association Grant not drawn	40	0	0
Royal Society Grant				150	0	0				
British Association Grant				10	0	0				
" " "				40	0	0				
Loans :—										
Royal Society				550	0	0				
W. W. Watts				50	0	0				
Sale Carbonadoes	284	10	0							
Less commission	7	2	3							
				277	7	9	Balance	165	16	2
				2,147	7	9		2,147	7	9

The experience gained in this attempt proved that, as some of us had feared from the first, England was too distant to be a base for the undertaking, and we expressed this opinion unofficially to our friends in New South Wales. They were the more prompt to accept the suggestion, because their machinery had been defeated by the peculiarities of the reef rock. It would have cut through sandstone, or even basalt, as an auger through a piece of wood, but an entirely new problem had been afforded by material which varied constantly from incoherent to comparatively hard. So repulse made them all the more determined to succeed, and the result was the despatch of the Second Expedition in 1897, the story of which, from the first beginning to its successful conclusion in attaining a depth of 698 feet, is told by

Professor DAVID in Section IV. To the expenses of this Expedition the Royal Society contributed a sum of £350, the larger share, as stated in his report, being defrayed by the Government of, and private subscription in, the colony.

But our friends were not yet satisfied, for the submarine contour of the island, determined by Captain FIELD'S soundings, suggested that the base of the coral reef might be very near, so the Boring was continued in 1898, as narrated in Section IV, until a depth of 1114 feet had been reached. To this the Royal Society subscribed £200. The whole of the core was sent to England, to be dealt with as Professor JUDD has described in Section X, and all the half-cylinders of core with duplicate portions of the looser material have now been returned to Sydney. The part retained in England has been placed in the British Museum, South Kensington.

When considerable progress had been made in working out the cores and other materials obtained in these Expeditions, Professor JUDD presented a preliminary report on the work to the Committee, and they, after considering it, authorised the Chairman to request the Council of the Royal Society to publish the results in the 'Philosophical Transactions.' The answer is given in the following extract from the 'Minutes' of the Council dated June 15, 1899 :—

Read a Statement by the Vice-Chairman* of the Coral Reef Committee, reporting upon the materials obtained by the recent Borings at Funafuti, and detailing the steps being taken for their complete examination, and asking the sanction of the Council to the Committee's undertaking the preparation of a monograph on the atoll of Funafuti on the following general lines, namely :—

A description of the whole core from the points of view of the naturalist and the chemist, forming the main feature of the monograph; together with brief notices of all papers dealing with the general results of the Expedition, and a list, with critical remarks of the species of animals and plants collected; the whole forming a volume of about 500 pages with plates.

Resolved: That the Coral Reef Committee be authorised to take steps for the preparation of a volume on Funafuti, on the lines above described.

In 1900 a sum of £116 was granted by the Council in aid of expenses partly connected with the preparation at Sydney of the maps in this volume, and £70 was received from the Government Grant Committee to defray sundry expenses connected with the working out of materials in this country.

In the beginning of 1898, before much advance had been made in working out the materials, and prior to the Third Boring, the Committee requested Professor SOLLAS to act as Editor of the volume already contemplated. But as time went on, I perceived more and more clearly that the Editor's task would not be a light one, and that it would press less heavily on a resident in London. Moreover, as not a little of it would be rather mechanical, I felt how much science would lose if my

* Prior to December 6, 1900, this was the strict title, the President of the Royal Society being in theory the Chairman.

old friend and pupil were diverted from the reorganisation of the Geological Museum and the work of the Chair at Oxford to which he had been recently appointed, and from more than one of the important original investigations on which he was also engaged. Thus, as my own time was—in the natural course of things—becoming less valuable, and the date of my retirement from the work of teaching was mentally fixed, I offered to relieve Professor SOLLAS of the more mechanical work of Editorship, and the Committee at a meeting held February 9, 1900, passed the following resolution :—

That the Vice-Chairman of the Committee be requested to aid Professor SOLLAS and the other members of the Committee by undertaking the general editorial supervision of the volume which is to be issued by the Royal Society.

Thus I am responsible for passing this volume through the Press, though I have had the advantage of consulting Professor SOLLAS whenever this was necessary. Proofs have been submitted to all Authors resident in England, but for misprints to the contributions from Australia I must bear the blame, and trust that any slips on the part of Author or Editor will be leniently judged, for under the circumstances the task has been far from easy. A bibliography of memoirs relating to materials obtained during the three Expeditions will be found at the end ot Section X, but it has been deemed needless to attempt one on either coral reefs in general or the Ellice group in particular. I should, however, mention, that since the printing of this volume began, an account of Funafuti has been published in Professor ALEXANDER AGASSIZ's admirably illustrated and most valuable work, "The Coral Reefs of the Tropical Pacific" ('Memoirs of the Museum of Comparative Zoology at Harvard College,' vol. 28, pages 212–229, Feb., 1903).

The large coloured maps of the different islets in the atoll, surveyed by the Expedition from Sydney, were executed, it should be mentioned, in that city in order to have the advantage of Professor DAVID's supervision. Thus, when received in this country they were already numbered. We have, therefore, found it advisable to designate the plates of scenery, &c., prepared in this country and intercalated in the volume, by letters of the alphabet; figures inserted in the text following the usual course.

Into the controversies about the development of coral reefs, those who have been concerned in the preparation of this volume have not attempted to enter. They have endeavoured to state facts and leave it to readers to interpret these for themselves. They trust that arduous and costly as this undertaking has been, it and the labours of those who have worked out its results have not been fruitless, and that the mass of information now acquired will be an important addition to Natural Science. At any rate the composition, zoological and chemical, of an atoll down to a depth of 1114 feet has now, for the first time, been made known. For this we have to thank the untiring energy of Professors EDGEWORTH DAVID and ANDERSON

STUART,* the liberality of friends in New South Wales and the Government of that colony, with whom, we on this side of the world ought also to include their then Agent-General Sir SAUL SAMUEL. Gratitude is expressed to these by name in the different reports, and we crave pardon in advance for any inadvertent omissions, pleading as excuse the number and the difficulties caused by the long distance between writers and printers. But as Chairman of the Committee from the beginning, I can realise more fully perhaps than most, how much we are indebted for the success of this undertaking to friends in, and the Government of, New South Wales, and trust that the one and the other will be satisfied by the results.

In the same capacity I may venture to acknowledge the valuable services of not a few workers on this side of the world. We are indebted to Professor RAY LANKESTER and to members of his staff at the British Museum of Natural History for frequent assistance. All the members of the Committee have given special help whenever it was needed. Sir W. J. L. WHARTON, Hydrographer to the Admiralty, has been untiring in his efforts, and we cannot but feel that we are greatly indebted to his good offices with that Department for the invaluable assistance rendered to the Expedition by H.M.Ss. the "Penguin," under Captain MOSTYN FIELD, and the "Porpoise," under Captain STURDEE. Our secretaries, Professor SOLLAS and Professor WATTS, have earned our gratitude for their constant help, and there are two other members of our Committee to whom we are under a more than ordinary obligation. Professor JUDD undertook, at the request of the Committee and with the sanction of the Board of Education, which thus gave a strong support to the investigation, to receive the cores despatched from Australia, to prepare the materials for and exercise a general supervision over their examination, and to have the chemical and mineralogical study carried out under his own eye at the Royal College of Science, South Kensington. The results, as will be seen from Sections XII to XIV, have proved to be highly interesting. Dr. G. J. HINDE, to whom the Committee also appealed for help, has devoted many months of labour to the minute study of the organisms comprising the cores, and I venture to say that the more his elaborate report (Section XI) is studied, the more its value will be appreciated. Their unselfish devotion to this most laborious task entitles them to the heartfelt gratitude of all lovers of Natural Science. May I also thank them for their constant kindness to myself in responding to questions, in reading proofs, and in supplying the defects of my own ignorance.

* When preparations were being made for the despatch of the First Expedition, a committee was formed in Sydney, by the initiative of Professor ANDERSON STUART, consisting of himself, Professor EDGEWORTH DAVID, Captain MOSTYN FIELD (in command of the "Penguin"), Mr. ROBERT ETHERIDGE, Jun. (Curator of the Australian Museum), Mr. C. HEDLEY (Conchologist to that Museum), and Mr. W. H. J. SLEE (Superintendent of Diamond Drills, Department of Mines).

SECTION I.

NARRATIVE OF THE EXPEDITION IN 1896.

By Professor W. J. SOLLAS, *D.Sc., LL.D., F.R.S.*

ON Monday, March 10, 1896, I left London to join the Orient s.s. "Oroya" at Naples, on board of which was Mr. STANLEY GARDINER, who had volunteered to accompany me to assist in the objects of the Expedition. After a pleasant but uneventful voyage, we reached Sydney on Saturday afternoon, April 18, and were warmly welcomed by Professor EDGEWORTH DAVID, who invited me to make his house my home till the "Penguin" was ready to start. The time I spent in his society, and that of Mrs. DAVID and her charming family, will always remain one of the most enjoyable reminiscences of my journey.

The Committee which had been formed in Sydney to co-operate with the Committee of the Royal Society had been active in making preparations for some time past, but there still remained some details to discuss, and meetings were held, at which I was present, on April 20, 23, and 27. These gave me an opportunity of becoming more closely acquainted with our friends and fellow workers, Professor ANDERSON STUART, Messrs. SLEE and ETHERIDGE, from all of whom I received the greatest kindness; I was also able to read before the full Committee the instructions with which I had been furnished by the Committee of the Royal Society.

The Admiral in command of the Australian Squadron hospitably entertained the members of the Expedition, and showed a close personal interest in its objects, which proved of assistance to us in many ways.

On Friday, May 1, we went aboard the "Penguin" and were warmly received by Captain MOSTYN FIELD, R.N., and his officers, Lieutenant DAWSON (now Commander), Lieutenant WAUGH, and Dr. COLLINGWOOD, Messrs. NARES and BREWIS. To Captain FIELD, who entertained me as his guest, I am under deep obligations; he spared no effort to render the Expedition a success, and by numerous acts of kindness did all that was possible to mitigate the discomforts attendant upon residence on an uncivilised island.

On Wednesday, May 13, we entered the beautiful harbour of Suva, Fiji, and spent two or three days in completing preparations for the survey of Funafuti; Captain FIELD was occupied most of the time in making preliminary observations with his magnetic instruments, while we, thanks to the kindness of the Hon. Dr. CORNEY and the Hon. JOHN BERRY, who had organised excursions for us, were able to see some-

thing of the geology of the neighbourhood and especially to study an interesting example of a raised coral reef. On May 16 we left, with many regrets, Suva and our hospitable friends, and passed out of the island through the tortuous Mbengha passage into the open sea. On the morning of May 21, Funafuti was in sight, and in the afternoon we steamed into the lagoon through the southern entrance. A boat put out from the shore to meet us, and Mr. J. O'BRIEN, the solitary white trader on the island (since dead), came on board to act as pilot. We dropped anchor in 10 fathoms, within a mile of the shore, and nearly opposite the native village.*

Captain FIELD at once landed with Lieutenant DAWSON, AYLES (the foreman of the boring party), and myself. We paid a visit to the "King" ELIA, and obtained his permission to do all that was necessary to carry out our project. We then proceeded to choose a site for boring, and selected a spot near the sandy beach of the lagoon, conveniently situated for the landing of gear, less than half a mile to the south and west of the village of Funafuti, and near the village well, which supplies a small amount of brackish but drinkable water. The work of landing was commenced the next morning, and completed by May 26. The erection of the boring apparatus was at once taken in hand, and on June 2, twelve days after our arrival on the island, all was in readiness for commencing operations. On June 3 the 6-inch tubes were driven into the sand, and by June 6 they had been advanced 30 feet; the 5-inch pipes were then entered and everything made ready for inserting the diamond crown and commencing to drill on Monday, June 8. On June 10 it was arranged that the work should proceed by shifts, so that the drilling might be carried on continuously day and night. During the first shift the crown had been advanced 20 feet, making the total depth then attained 52 feet 9 inches, and in course of this fragments of highly cavernous coral rock were brought up in the core barrel from a depth of between 40 and 50 feet.

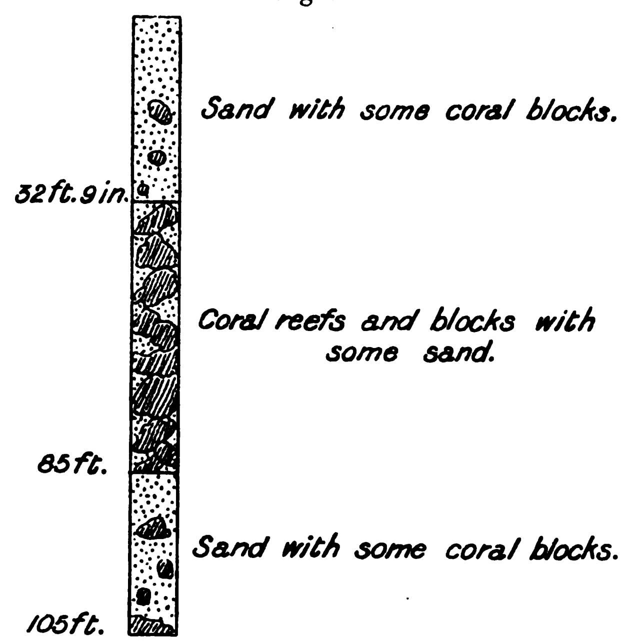
On June 11, a depth of 85 feet having been reached, it was found necessary to ream the hole preparatory to lining, and by June 15 the necessary reaming and lining had been completed. Up to this, although we had been somewhat disappointed at our slow rate of progress, occasioned partly by the unfavourable nature of the ground and partly by the frequent failure of our machinery, we had anticipated nothing worse than the possibility of finding our allotted time exhausted before we had reached a depth of 1000 feet; but now, on setting the crown to work, it very soon ceased to advance, and AYLES shortly afterwards came to me to announce that, in his opinion, the boring was a failure. Nevertheless, some further progress was subsequently made, and on Tuesday, June 16, a depth of 105 feet was attained. It then became once more necessary to ream and line the hole. Attempts to ream were continued all through Wednesday and Thursday but without success, for sand poured into the hole and the reamer could not be driven through it. Efforts were made to

* In the next few pages some extracts from the Report already published in the 'Proceedings of the Royal Society' (vol. 60, p. 502), are incorporated. "Sand" denotes material of organic origin.

remove the sand by a sand-pump, but proved unavailing, the sand flowing in faster than it could be pumped out. AYLES assured me that it was impossible to descend another foot, and that he considered further labour to be time and money thrown away. It was decided, therefore, to abandon this bore-hole.

The structure of the ground passed through was as follows :—

Fig. 1.



On informing Captain FIELD of our difficulties he delayed the departure of the "Penguin" which was about to sail to meet the Admiral at Suva, and came ashore to see if he could render us any assistance. We were inclined to suspect that our want of success might be due to exceptionally unfavourable circumstances dependent on the locality we had selected for the bore-hole; it was close to the lagoon, and our operations from the first had been conducted in the loose sand of the lagoon beach. We determined, therefore, to look for some place where solid rock appeared at the surface as far from the lagoon and as near the outer reef as it might be possible to get.

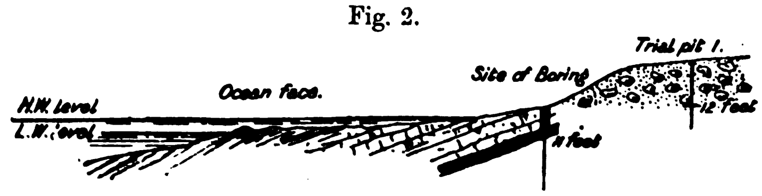
A part of the island, to which we shall refer subsequently, as the "Mangrove Swamp," seemed to offer us such a site as we were in search of; particularly as its surface appeared to be formed of solid coral rock. On investigation, however, it was soon found that the dead masses of *Porites* and *Heliopora*, of which this rock is composed, could be easily dislodged with a spade and crowbar, and that they formed only a thin layer over a deposit of fine silt and sand below.

We then turned our attention to the solid platform of rock which forms the ocean side of the island. It was not easy, however, to find a place to which we could transport our machinery; the difficulties of landing on a rocky shore rendered several promising spots inaccessible by sea, while the absence of wheeled vehicles or even

wheels, and the nature of the ground, seemed to put transportation by land out of the question.

At last, however, Mr. HEDLEY pointed out to me a portage called Luamanif, used by the natives for dragging their canoes from the lagoon to the seaward side of the island, which at this place is very narrow, about 70 yards across. As this seemed a good landing-place, I submitted it to the consideration of Captain FIELD, who, after a personal examination, agreed that we might safely make use of it. AYLES and his party were then set to work to sink trial pits on the line of the portage; one of these, situated 70 feet from the high-water mark on the seaward face of the reef, was sunk 12 feet through sand and blocks of coral, when operations were brought to a close owing to the influx of sea-water at high tides. Two other pits were then commenced nearer the sea and a little to one side (north) of the portage, at the margin of the solid platform of rock, which extends down to the growing edge of the reef and is covered by the sea at high-water. These passed through sand and fragments of coral. In the most northern of the two pits the sand was somewhat consolidated, and so, proceeding a few yards further north, as far in that direction as it would have been possible to transport our machinery, we opened another pit, which was sunk for a depth of 11 feet through fragments of coral, crystalline coral limestone, and partly consolidated sand. The bottom of the pit was 2 feet below the seaward margin of the reef, and, as we were not inconvenienced by an influx of sea-water, and AYLES was of opinion that the rock would "stand," we decided to make our new venture at this spot (see fig. 2). Taking into consideration the difficulties of trans-

Fig. 2.



porting our apparatus, I do not think a more favourable locality could have been chosen; it was close to the very edge of the rocky platform, which is so hard that DARWIN, speaking of a similar platform in the case of another reef, says "I could with difficulty and only by the aid of a chisel procure chips of rock from its surface"; and as near the sea as it was prudent or even possible to go. Indeed, we had at first some doubt as to whether our pumping pipes would "live" in the surf of the ocean margin, and feared that the high-water spring tides might inundate the shaft; our fears in these respects, however, proved to be groundless.

Captain FIELD and myself were impressed with the need of additional boring apparatus, and he proposed that AYLES should go to Sydney to see if it could be procured. I gave much anxious consideration to this project, and discussed it with my colleagues, Messrs. HEDLEY and GARDINER, and with AYLES. The information I received from AYLES was not encouraging. He stated that we should require a

complete equipment of lining tubes from 10 inches down to $2\frac{1}{2}$ inches in diameter, that 10-inch tubes were not to be had in Sydney, and that, even if we succeeded in obtaining all the appliances we required, the success of the boring would not then be by any means assured.

For a doubtful result I did not feel justified in incurring the certain increase in our expenditure which a journey to Sydney would have involved; the question of time had also to be considered, for had AYLES gone thither we should on his return have been commencing our boring at or after the date the Committee had considered it would have been completed. Finally, it appeared that the new locality we had chosen for our work offered fair prospects of success.

The shaft already sunk to a depth of 11 feet was then timbered with Pandanus logs, and arrangements were made for carrying down a hole by jumping with a 6-inch chisel. AYLES spoke of getting as far as 50 feet by this means, and then lining the hole with 6-inch tubes, but, after sinking 4 feet, he declared it impossible to proceed further in this way; the chisel could not be made to continue sinking in a straight line, the labour was too exhausting, and progress very slow. It was decided, therefore, to begin boring, AYLES being very hopeful, as the hole "stood" well. On Thursday, June 25, we accordingly made arrangements to shift our boring gear to the new site, and by Saturday, June 27, this work was completed, chiefly by native labour, and at a cost of about £10. The boilers were rolled along the beach, the rest of the machinery was taken by water, and all subsequently dragged, rolled, or carried across the portage. Lieutenant WAUGH lent us valuable assistance, during the absence of the "Penguin," in this work.

Boring was commenced on Friday, July 3, and by 5 o'clock we had sunk another 4 feet; progress then became rapid, and on Saturday evening, when work was knocked off, we had descended in all 46 feet. Very little "core," however, was obtained, and at times the boring bit met with hardly any opposition as it advanced, seemingly passing through a vacant space. Since the water pumped into the hole no longer flowed out above, but found its way out by some communication with the sea below, it was impossible to determine whether or not some sand might have been present. It was clear, however, that the coral rock through which the "bit" advanced was highly cavernous.

On Monday, the hole became filled with fallen fragments and some sand; it was evident, therefore, that the sides would not hold, and so recourse was had to lining; by Thursday, July 9, the hole had been reamed and lined down to 45 feet, and the work of boring was resumed. On pumping, we had the satisfaction of seeing the water flowing out of the top of the hole, but our joy was short-lived, for, on Monday, July 13, the water was again lost. On Tuesday, July 14, we had reached 65 feet, passing for the last 20 feet through sand and coral. Subsequently we attained a depth of 72 feet, and could then proceed no further. We worked all Thursday and Friday with the sand-pump, but with no success; the bottom of the hole was

surrounded by quicksand containing boulders of coral, and as fast as the sand was got out, so fast it flowed in and faster. The water pumped down disappeared through the sand, boring and *à fortiori* reaming was impossible, and the tubes could not be driven owing to the interspersed boulders. Had the tubes been provided with steel driving ends we might have forced them down; as it was, the effect of driving them was simply to curl in the lower end. Had we been provided with 4-inch tubes we could have made a fresh start, and might have descended another 30 or 40 feet, but even then ultimate success would not have been ensured, for the chance of meeting again and again with intermixed sand and coral remained always open, and every such encounter would have required lining tubes of diminished calibre.

Baffled in our endeavours, and with no other part of the island offering more hopeful prospects of success, we had no alternative but to abandon the undertaking, and on July 30 were taken from the island in the "Penguin," and returned to Fiji. On landing there we had the mortification to learn that additional apparatus was then on the way to Funafuti, our friends in Sydney having with great generosity at once despatched machinery for driving through sand on receipt of a letter I had sent informing them of the failure of our first bore-hole. We had no reason to expect such spontaneous assistance, and even had we been fortunate enough to have remained on the island till the machinery arrived, we probably should not have accomplished the object we had in view, though we possibly might have carried the borehole down to a depth of about 400 feet.

A very free communication must have existed between the bore-hole and the sea, for whenever a big roller broke upon the reef the rods lifted, and after the lining had been withdrawn, water spurted out of the bore-hole with the fall of every wave. The open nature of the reef is further indicated by the fact that the sea water rises with every tide to fill certain depressions, which occur in many places in the middle of the island; as the tide ebbs this water flows away down fissures, often so rapidly as to form little whirlpools.

Wherever I have seen the reef growing it has always presented itself as clumps or islets of coral and other organisms with interspersed patches of sand, and the borings would seem to indicate that it maintains this character for a very considerable depth, and possibly throughout. The structure of the reef appears indeed to be that of a coarse "sponge" of coral with wide interstices, which may be either empty or filled with sand.

As regards the nature of this "sand," it is important to observe that it does not consist of coral *débris*; this material and fragments of shells forming but an insignificant part of it; calcareous algæ are more abundant, but its chief constituents are large foraminifera, which seem to belong chiefly to two genera (*Orbitolites* and *Tinoporus*). It covers a considerable area of the islands, and has accumulated during the memory of the inhabitants to such an extent as to silt up certain parts of the lagoon. This and the abundant growth of corals and calcareous algæ, such as *Halimeda*, lead to the belief that the lagoon is slowly filling up.

A suggestion has recently been made that more light is likely to be thrown on the history of atolls by a study of ancient limestones in the British Isles than by boring in existing reefs. The first essential, however, for such a study would appear to be a knowledge of the structure of living atolls, for, without this, the identification of others forming a part of the earth's crust might remain more or less a matter for conjecture. So far as the structure of Funafuti has been proved by borings, it is scarcely what a field geologist might have anticipated, and if deposits of a similar nature and origin had been encountered in, say, the Mountain Limestone, it is doubtful whether, previous to the borings in Funafuti, their interpretation would have been easily reached.

Although the boring proved a failure, several other objects of the expedition were attained with complete success. Messrs. HEDLEY and GARDINER made a thorough investigation of the fauna and flora, both land and marine. Dr. COLLINGWOOD obtained a good deal of information of ethnological interest, and we all made a fairly complete collection of native implements and manufactures. A daily record was kept of maximum and minimum temperatures, and of the readings of dry and wet bulb thermometers. These have been reduced by the Astronomer Royal of New South Wales, Mr. H. C. RUSSELL, F.R.S., to whose kindness we were also indebted for the loan of meteorological apparatus. The results are given in Section II.

The most important contribution, however, is afforded by the investigations of Captain FIELD, who made a complete topographical survey of the atoll, and a vast number of soundings both in the lagoon and the outer sea; he also carried out magnetic (Section III) and tidal observations.

The short length of core obtained from the bore-holes, together with the material brought up by the sounding apparatus used by Captain FIELD, and some other specimens, were, on my return home, placed by me in the hands of Professor JUDD, and a description of them will be found embodied in the report by Dr. G. J. HINDE, F.R.S., on the material of the core.

Description of the Atoll.

The general outline of the atoll, as shown on the Admiralty Chart (frontispiece), constructed by Captain FIELD, bears a grotesque resemblance to the profile of a man's head (see also Plate B, page 62). The "face" looks westward, the occiput eastward, and its protuberance marks the broadest part of Funafuti proper, which is the largest islet of the group, and the only one permanently inhabited.

The ring of reef awash between tides forms a fairly continuous narrow band, regularly bounding the lagoon, except in the N.W. quarter, where it becomes much broken up and various in direction. The longest continuous stretch of reef is about 16 miles in length; it commences at the top of the "head," on the eastern side of the passage called Te Ava i de Lape, runs at first due east, then bends round to the S.S.E. as far as the occipital protuberance, when it is diverted to the S.W., and ends

against the passage of Te Buabua, which is separated from the next passage on the south, Te Ava Mateika, by a very short interval of reef. Beyond Te Ava Mateika it bounds the attenuated "neck" of the island, extending all round this without a break, and northwards as far as Te Ava Fuagea, where it is inflected into the lagoon, bounding like a thick lower lip the narrow and deep channel of Fuagea, which is nowhere less than 23 fathoms in depth. The lagoon is very shallow within the "neck," and floored by a thin solid crust; the streams of sea-water which drain it between tides carry with them abundant sand composed of foraminifera.

The "nose" is a remarkable feature of the atoll, its root being a broad expanse of tide-washed reef, and it extends out into the ocean as a growing bank of coral, submerged to a depth of 7 fathoms for the most part, but rising near its extremity into the reef Te Akau Fuafatu, which reaches to within 3 fathoms of the surface. This tendency to grow outward into the ocean is again seen further north in Te Afua Sari, which forms a sort of brow-ridge to the profile, and bounds a second deep and narrow passage, Te Ava Tebuka.

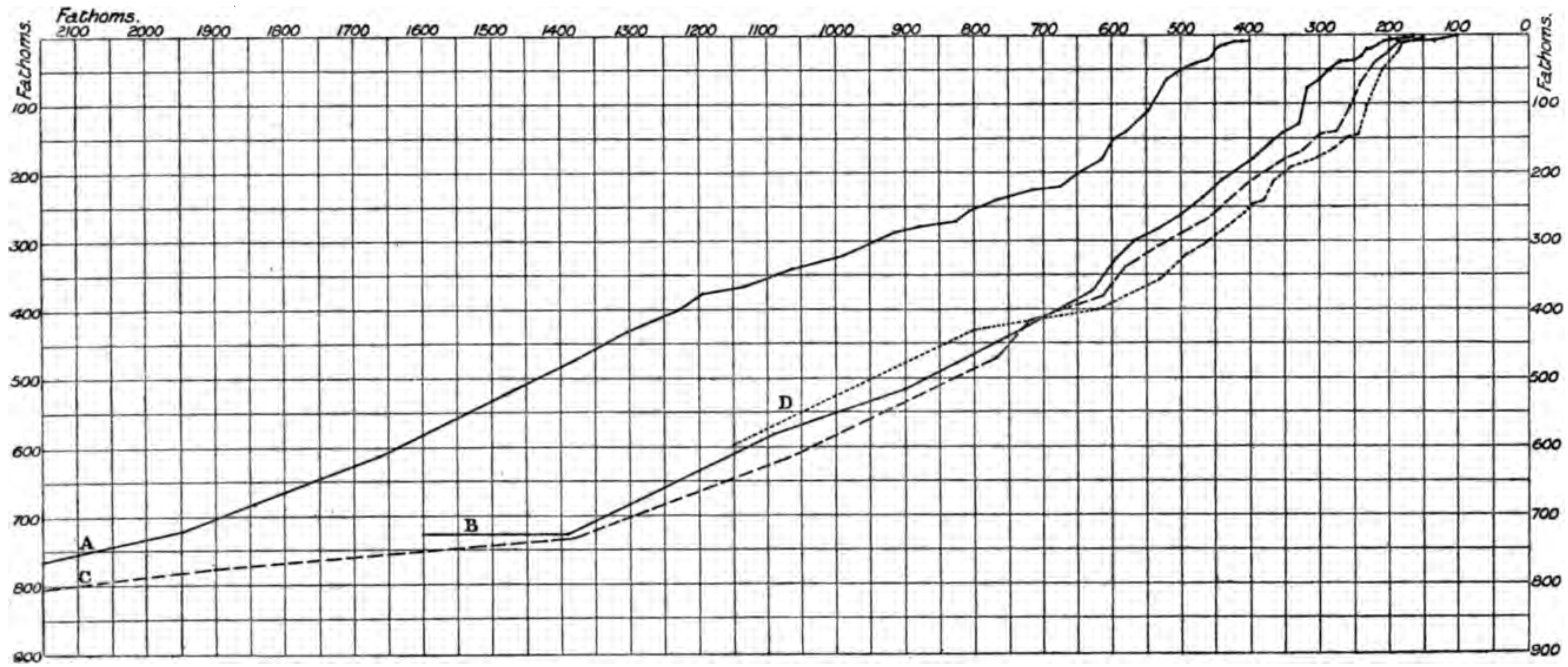
The prevailing winds are easterly (as is the set of the ocean currents), so that the most irregular part of the reef is on the leeward side.

The floor of the lagoon is tolerably even, gradually deepening from the shore to an average depth of 20 or 25 fathoms, attaining in four cases an extreme depth of 30 fathoms, and rising in many others to form slightly submerged shoals, or even reefs awash, of which Te Akau Tuluaga in the middle of the lagoon is the largest; this dries to 4 feet, and having landed on it, I collected from it foraminiferal sand and molluscan shells, as well as dead and living coral.

The submarine configuration of the atoll was very fully investigated by Captain FIELD; in addition to numerous deep-sea soundings taken all round the island, four profiles were obtained by as many series of soundings run from the seaward face of the reef outward. The successive soundings of a series were separated by the following intervals:—

For a depth between		0— 40	fathoms every	10	yards.
,,	,,	40— 70	,,	20	,,
,,	,,	70—100	,,	30	,,
,,	,,	100—150	,,	40	,,
,,	,,	150—200	,,	50	,,
,,	,,	200—300	,,	60	,,
,,	,,	300—400	,,	70	,,
,,	,,	400—500	,,	80	,,
,,	,,	500—600	,,	90	,,
,,	,,	600—700	,,	100	,,
,,	,,	700—800	,,	200	,,

The results are shown on fig. 3, reduced from profiles plotted to true scale, from



Scale both Horizontal & Vertical :- 10 fathoms represented by 1 m.m.

Fig. 3.—Profiles of the Atoll.

A. Off S.W. corner of Funafuti Lagoon. Line of Section S. 24° 10′ W. (true).
B. Off Eastern Extreme of Funafuti Lagoon. Line of Section N. 37° 30′ E. (true).
C. Off Western Extreme of Pava Islet. Line of Section N. 19° W. (true).
D. Off Western side of Funafuti Lagoon. Line of Section S. 9° 55′ W. (true).

Captain FIELD's soundings, and communicated by Admiral Sir W. J. L. WHARTON. They present a close general resemblance, with some interesting peculiarities in detail.

The 500 and 600 fathoms' contour lines follow approximately the outline of the atoll, and are bayed outwards around the "nose" and "brow-ridge," in conformity with the general outline of these features. The average distance of these contour lines from the shore is slightly greater on the westward (leeward) side of the atoll than on the eastward, so that the slope on the latter side is somewhat the steeper of the two.

The atoll is an isolated mountain rising very gently from a depth of 2000 fathoms; above 1000 fathoms the slope begins to increase, and between 600 and 700 fathoms the average slope for three of the profiles is 22°, between 500 and 600 fathoms nearly 25°, between 400 and 500 fathoms it remains about the same, but this is owing to the existence of a very gently inclined shelf, 350 yards in width, with a dip of only 9° or 10°, which occurs between 400 and 450 fathoms in the profile of the west side (D). If this be excluded, the average slope becomes 28° to 29°, and there is a steep cliff on the north profile (C) with a slope of 48°; this cliff is interesting, since it occurs lower on the flanks of the atoll than any other. Its base is 2820 feet below the sea-level, and it rises through a vertical height of 330 feet. The sounding apparatus indicated coral bottom at the foot of the cliff. From 400 fathoms upwards a distinction is still maintained between the southern profile and the three others, which, however, are in close agreement between themselves. They present an average slope of nearly 40°, which is interrupted by precipitous and lofty cliffs, the least steep having an angle of 65°, the steepest, which is 300 feet in height, of 78°. The southern profile is marked

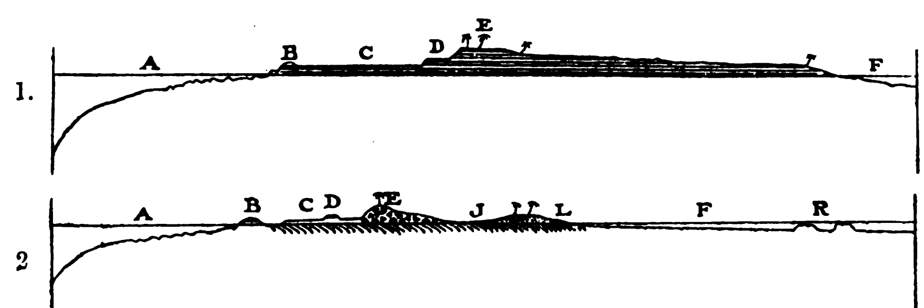


Fig. 4.—Diagrammatic sections through the rim of Keeling (1) and Funafuti (2) Atolls.

A. Constantly submerged portion of the reef.
B. Nullipore rim.
C. Reef-flat of coral-rock.
D. Ledge of coral-rock.
E. Seaward or outer ridge.
F. Floor of lagoon.
J. Central flat of islet.
L. Lagoon mound.
R. Growing reefs of lagoon.

by a greater extension seawards of the shallow reef flat, and by an average slope of only 26°, but this is greatly exceeded between 65 and 220 fathoms, the average over this range being nearly 40°, and it presents two steep cliffs, one of 65°, and the other of 56° to 57°, with a height of 270 feet.

(1) Ocean Shore of Funafuti Island.

(2) Ocean Side of Funafuti Island, near Site of Second Boring.

The soundings showed a coral bottom at great depths round the atoll, not uncommonly between 500 and 800 fathoms, and in one instance, the most northern sounding marked on the chart, sand and coral are shown at a depth of 1354 fathoms. This spot is situated a little over $3\frac{1}{2}$ sea miles from the nearest part of the reef.

The belt of land which separates the ocean from the lagoon presents much the same character as in the case of Keeling Atoll, described by DARWIN. A glance at the two diagrams (fig. 4) is sufficient to show this.

The "outer edge" of DARWIN's diagram (1 of fig. 4) corresponds to our "nullipore rim," which owes its deep madder-red tint to one group of these algæ. Forming a low mound which rises to a height of about one foot above low tide, at the extreme seaward margin of the land, the nullipore rim is visible for the greater part of the day; and by its rich colour produces a pictorial effect so fortunate as to seem placed there almost by design; it is the last note of colour offered by the land, and pleases both by its contrast with the whiteness of the surf, and by its perfect harmony with the deep blues of sky and sea. Its algal layers extend on to the platform behind, and on breaking away fragments of this with a hammer, it is found to be tunnelled through with numerous close-set tubes and other burrows, which harbour a rich variety of life.

Behind the rim lies a rocky platform, DARWIN's "flat of coral rock" (C of fig. 4); this is covered with a few inches of water next the rim, even at low tide, and its middle portion is frequently somewhat higher than either its seaward or landward sides, and so becomes exposed during the ebb as a broad, low swell of rock bounded on either hand by shallow channels, and supporting numerous pools upon its surface. (See Plate A, upper figure, where A is the nullipore rim; B, the shallow depression in the reef flat; C, the reef flat.)

The reef-flat passes into a gently sloping glacis, which rises landwards to about ordinary high-water level. (Plate A, lower figure, where the outer line of waves marks the nullipore rim; the reef flat is submerged, the glacis is seen rising from the sea, ending landwards in a miniature scarp, succeeded by loose sand, &c.; palms crowning the outer ridge, here rather lower than usual.)

Both flat and glacis consist of hard limestone, smoothed by the waves for the most part, but becoming rougher nearer the landward end. It is with respect to this that DARWIN remarks:*—"I could with difficulty, and only by the aid of a chisel, procure chips of rock from its surface, and therefore could not ascertain how much of it is formed by the aggregation of detritus, and how much by the outward growth of mounds of corals, similar to those now living on the margin," and I fancy the once prevailing impression that a coral-reef would be found on boring to consist of hard limestone, partly owed its origin to the universal presence of this rock on the seaward face of the atoll between tides. Our boring operations, especially in our second attempt, showed that the limestone is of no great thickness, and that uncon-

* 'Coral Reefs,' p. 15 (Ed. 3).

solidated deposits lie beneath it. It varies considerably in character, but always consists for the most part of fragmental coral material, together with foraminifera, remains, of calcareous algæ and other organic remains of no great size, such as molluscan shells or spines of echinoderms. On the reef flat itself calcareous algæ contribute largely to its bulk, and by their growth may have had much to do with its consolidation. On the glacis it was sometimes found to consist almost entirely of foraminifera, which had been cemented together by the deposition of carbonate of lime from solution. In DARWIN's diagram the glacis is not distinguished from the flat, and "a low projecting ledge of brecciated coral-rock, washed by the waves at high water," is introduced (D of fig. 4) as a general feature. This, I think, may correspond to certain pinnacles, ridges, or cliffs which rise upwards in certain places from the glacis of our atoll, and of which we shall have more to say presently.

The glacis is succeeded on the landward side by a steep ridge, usually formed of loose fragments of corals, but sometimes of large water-worn pebbles, which have been piled up by the waves during storms of unusual violence. This is the slope marked E in DARWIN's diagram; we usually called it, during our residence on Funafuti, the "hurricane beach," a term which is appropriate enough to its seaward face, but not to the whole ridge, and as the land on the lagoon side also, at least in part, owes its existence to unusual storms, another designation would seem to be needed; I propose to call it, therefore, the "seaward" or "outer ridge." It rises with a steep slope to the summit, which may be a sharp edge or a flat surface a few yards wide, and then descends at first somewhat steeply and afterwards more gently towards the interior of the island.

Passing now to the lagoon side of the island we encounter a widely different scene; corals and coral reefs flourish here and there in luxuriant growth, but build no continuous bank, and we miss the nullipore rim which forms so definite a boundary to the seaward coast; on the other hand, resemblances are not wholly wanting, a rocky platform made up of consolidated coral *débris* and other calcareous material fringes a great part of the shore and reminds us of the seaward glacis, though its slope is far more gentle; in one instance, where it was uncovered for 80 yards, the tide being nearly low, the rise was found by careful levelling to be 1 foot in 240. Sometimes it ends in low cliffs, 3 or 4 feet in height, exposing the hard stratified rock in alternating beds of pebbles, sand-stone, and coral *débris*; sometimes it passes out of sight beneath a wide sweep of foraminiferal sand.

Sand, or sand mingled with fragments of corals, rises from high water to form a broader or narrower strip of land which descends on the other side towards the outer ridge. This has been driven up by wind and wave during times of storm, and thus is also a "hurricane beach"; it may be distinguished as the "lagoon mound." Its slopes on either side are insignificant as a rule compared to those of the outer ridge, and it usually consists of much finer grained material, frequently, as already mentioned, of sand, more rarely of rounded pebbles or large fragments of corals.

The lagoon mound is not shown in DARWIN'S diagram, which represents the surface of the islet as continuously sloping from the outer ridge to the lagoon, as it is expressly said to do in the descriptive letter-press. DARWIN was fully acquainted, however, with both the existence of the mound and its origin, for he states a little further on (p. 16) that "the little waves of the lagoon heap up sand and fragments of thinly branching corals on the inner side of the islets on the leeward side of the atoll . . . . but the land thus added is very low."

On Funafuti, the distinction between the ocean ridge and the lagoon mound is sometimes very sharply marked; on the broader parts of Funafuti islet they are not only obviously independent features, but also are widely separated from each other by an intervening plain, the black and rugged surface of which lies somewhat below high-tide level, so that at full "springs" sea-water oozes up through it and gives rise to scattered pools. This plain may be called the "central flat" (J, fig. 4); it is the exposed surface of a sheet or series of sheets of consolidated coral breccia, resembling the stratified coral rock and calcareous sandstone of the outer and inner platforms.

As the islet grows narrower to north and south the central flat becomes correspondingly reduced in breadth and the outer ridge and lagoon mound approach one another till they meet, and then pass into each other, till at length scarce any sign of a depression can be seen between them.

The structure of the central flat is best displayed in the interior of Funafuti islet a few yards north of the site of the third bore-hole; here it had been eaten away by the solvent sea-water, leaving steep-sided gullies some 3 or 4 feet deep, on the sides of which sheets of coral breccia were plainly visible. During a falling tide, when a foot of water covered the floor of the northernmost one of these gullies, I have seen little whirlpools, like those made when the plug is removed from the bottom of a bath, swirling over holes in the rock, and thus affording visible evidence of the free communication which exists between the middle of the island and the sea. In other cases where the holes were numerous enough to form a sieve no whirlpools were formed. A more striking evidence of the ready access which is open to the sea is to be found, as will appear later, in the Mangrove Swamp.

Glancing backwards over the observations we have already made, it will be seen that on the seaward side of the islets a sheet of hard limestone exists and extends from the nullipore rim up to the ocean ridge, beneath which it disappears, but on crossing this ridge a similar rock is again met with on the central flat, and though for a second time lost when we trace it up to the inner mound, it, or a rock very like it, reappears to form the cliffs and marginal floor of the lagoon. This suggests at once that the hard rock is continuous from lagoon to sea, nor is this supposition unsupported by evidence; for at the eastern end of the little islet of Pava, one of the northernmost islets of the atoll, the rock of the ocean glacis can be seen extending

continuously beneath the sand of which this islet consists, till it passes into the platform of the lagoon. The habitable land of the reef thus rests upon a foundation of consolidated coral breccia, calcareous sandstone and conglomerate; these forming a series of deposits of no great thickness, as is shown by the fact that in neither of our bore-holes were hard rocks encountered for many feet below the surface.

The history of this superficial sheet of rock is a matter which demands a careful investigation, and we shall find many problems involved in its study. One of the first facts to arrest my attention in my wanderings on the lagoon side of Funafuti islet was the constancy with which the slabs of coral which form much of the breccia beds slope towards the ocean; in many cases they are arranged in imbrication one upon another, all sloping in the same direction away from the lagoon. This disposition is rendered all the more striking by contrast where the hard rock protrudes from a bank of loose pebbles forming the existing beach; the pebbles slope towards the lagoon, the coral slabs away from it (fig. 5). Repeated observations showed that this arrangement is general, and not confined to one locality; further, in the case of Pava it is continuously maintained beneath the islet from the lagoon to the ocean side.

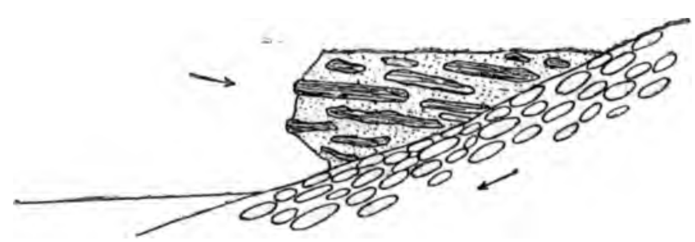


Fig. 5.—Lagoon cliff of consolidated coral rock north of the village of Funafuti. The slabs of coral in the rock dip oceanwards; the pebbles of the modern beach towards the lagoon.

Cases occur in which the hard rock crops out on the ocean side of the outer ridge; the coral slabs and the pebbles of the beach have then the same direction of slope (fig. 6).

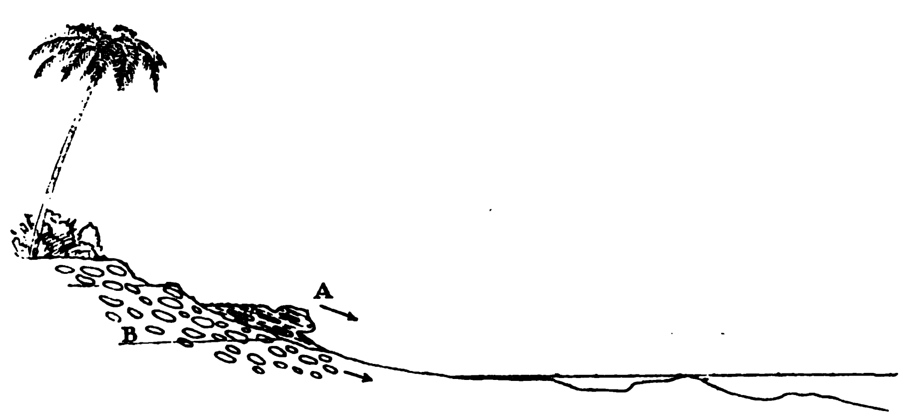


Fig. 6.—Cliff of coral-rock projecting from the side of the outer ridge, here formed of large pebbles. The pebbles and the elongated fragments in the coral-rock both dip in the same direction, ocean-wards.

Since the fragments of the hard rock, which forms the floor of the islands, thus slope in one direction, *i.e.*, from lagoon to sea, and since this is the direction which fragments now assume under the action of the ocean waves, we are led to conclude that there was once a period in the history of the atoll when neither outer ridge nor lagoon mound were in existence. The ocean then washed right across the reef into the lagoon, driving before it corals, whole and in fragments, and other calcareous *débris* to form the superficial hard crust, which supports the islets, and extends from under them as the remainder of the reef now awash between tides (fig. 7).

Fig. 7.—In illustration of the mode of origin of the rock, which forms the basis of the islets, and encrusts the summit of the Atoll.

A second feature of equal importance is the occurrence of pinnacles of hard rock projecting from the shore platform (fig. 4, D), and rising above the waves at mid-tide like a miniature sea-stack. It was with no little surprise that I encountered one of them on taking my first walk along the ocean beach ; it stood some four or five feet high, and the sea was breaking upon it heavily, bursting over it in great fountains of spray; the comparison with a sea-stack was inevitable, equally so the inference that the ocean platform is a plain of marine erosion; and in my notes written at the time I find a sentence to the following effect : "If this be so, some important change must have occurred since the coral breccia was formed and consolidated. Two views are possible, one that the pinnacle represents the core of an ancient outer ridge, which by a depression of the island or otherwise has been brought within the denuding action of the waves; the other, that it may be the surviving part of an ancient reef, which has been elevated and denuded since its growth."

Similar pinnacles were subsequently observed in numerous localities, and they came to be regarded as common characters of the reef; they are met with frequently at the ends of the islets (fig. 8), but also along their face, sometimes they form a linear series, and sometimes are replaced by a more or less continuous line of cliff,

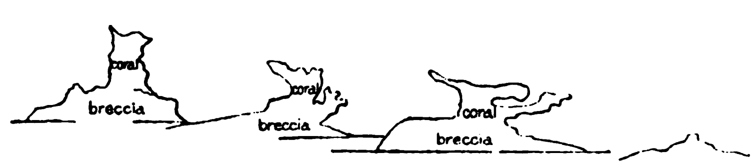


Fig. 8.—Pinnacles of coral-rock at the extremity of Pava islet.

especially on Funafuti islet. They are dry at low tide, and not completely submerged at ordinary high-tide level, above which they project some two or three feet. The lower part bears obvious marks of marine erosion and is usually undercut; the upper, exposed to sub-aërial agents, is fretted into complicated and fantastic forms, partly due to the weathering-out of the corals which enter into its constitution.

The lower part of the pinnacles is in many cases obviously composed of fragmentary corals, forming a breccia, continuous with that of the ocean platform; the upper part has at first sight much more the appearance of coral that has grown in place, though it is hard to say how much of its branching irregular form is merely the result of sub-aërial weathering. As a good deal depends on this point I naturally paid considerable attention to it, and examined very carefully one pinnacle in particular. It presented many branching forms of coral rising upwards in the direction of growth, and some turbinate forms still standing on a narrow base, though a few were evidently overturned. I was anxious to obtain independent testimony in this matter, and consequently invited my companions Messrs. GARDINER and HEDLEY to examine the pinnacle along with me; but on doing so they arrived at contradictory conclusions, one holding that the corals had grown in place, and the other, that they had been washed into position by the waves. Subsequently I examined many similar pinnacles, and though frequently on the point of deciding in favour of their having grown where they are found, I was never able to come to a quite definite conclusion. It is very easy to be deceived in the matter; on one occasion when I thought I had found an indubitable instance of a coral still retaining its original position of growth, I discovered on breaking it open with a hammer a *Tridacna* shell enclosed within, which was obviously inverted.

The fact, however, that their basal part consists of breccia, and not of once growing reef has some significance, for this must have been formed when the ocean was washing fragments across the reef into the lagoon; and if the upper part was formed by coral growth in place this would involve a subsequent subsidence, since followed by elevation.

The question raised by the existence of these pinnacles is rendered all the more difficult by our almost total ignorance of the conditions under which the consolidation of loose superficial *débris* is effected. Evidence of disintegration and erosion met us on every hand, and wherever the solid platform was exposed to the fury of the breakers it was in process of being broken up and driven inland; indeed much of the material of the outer ridge has been contributed by the destruction of the hard platform; but nowhere could I discover any evidence of consolidation in progress. Where nullipores are in active growth they serve to cement together whatever material is associated with them, but much of the hard rock of the superficial strata consists of calcareous sand and rounded pebbles cemented together by carbonate of lime, deposited from solution without the intervention of organic agency. In making preparations for our second boring, we dug several trenches, as much as 10 to 12 feet deep, in the loose material of Funafuti islet without discovering any hard deposit till we sank a pit near the seaward margin, when we encountered a loosely cemented bed of foraminiferal sand at a depth of 11 feet. This locality, however, may have been an exceptional one; it occurs where the land is so low that the natives use it as a portage

for their canoes when they wish to cross from the lagoon to the ocean; it may therefore represent a channel only recently filled up. A similar explanation may be given of the absence of hard deposits in the upper 10 or 20 feet of sand passed through in the first boring, for much of the sand in the immediate vicinity of this is certainly of recent accumulation. No evidence of consolidation is afforded by the walls of the wells which the natives have sunk in the sand to obtain fresh water.

When sea-water, under the influence of the tides, circulates freely through the islands, it exerts a solvent action on the coral rock, as already pointed out in describing the gullies in the central flat of Funafuti; but when its movements are impeded, as in passing through an accumulation of sand and coral fragments, conditions may occur which will be favourable to the deposition of calcium carbonate. DARWIN seems to have assumed something of the kind, for when endeavouring to account for the existence of his ledge *D*, which corresponds to our pinnacles and pinnacle ridges, he says: ". . . the lower fragments [of the outer ridge] are firmly cemented together by percolated calcareous matter" (p. 17). The level of saturation in a pile of sand and coral fragments will vary with the tides and the rainfall; the moist sand within the limits of this varying level will lose water by evaporation, which may thus bring about a deposition of dissolved calcium carbonate and a consequent consolidation of the loose material. In this way the lower and inner region of the outer ridge may possibly, as DARWIN seems to have supposed, become converted into hard rock. We have no direct evidence to show that this is the case; but assuming for a moment it is so, we may proceed to enquire whether the existence of the pinnacles may not possibly be accounted for on the hypothesis of a positive movement of the sea-level.

Thus, let the condition of the atoll at some former period of its existence, when the sea-level was, by hypothesis, lower than it is now, be represented by the diagrammatic section below (fig. 9):—

Fig. 9.—Hypothetical section through the summit of the Atoll, previous to an assumed subsidence.

Fig. 10.—The same submerged, the line marked 1 represents the former sea-level, that marked 2 the existing level.

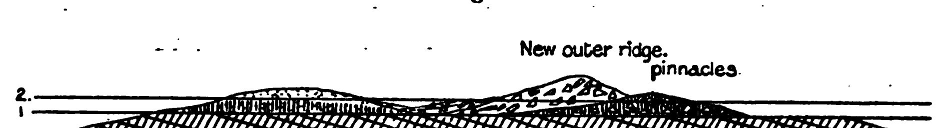
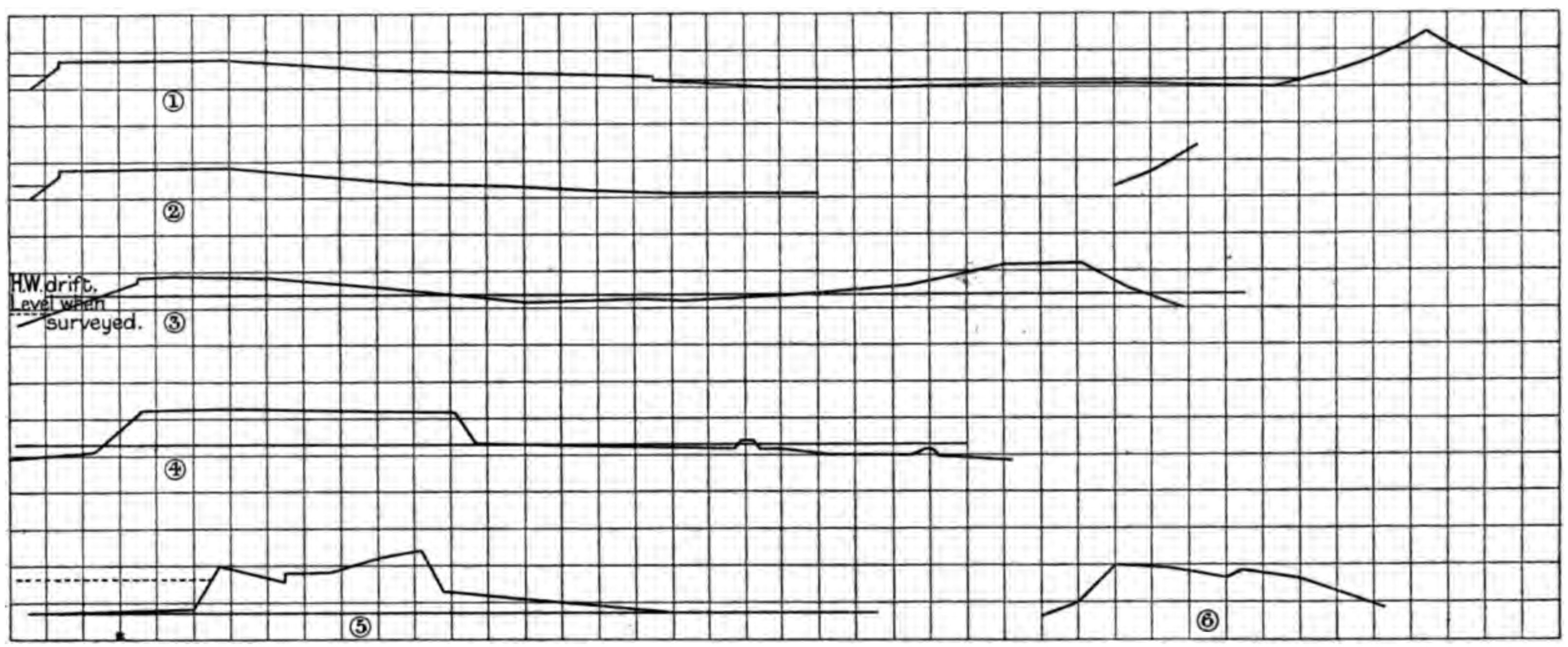


Fig. 11.—The same, showing the consolidated core of the original outer ridge, exposed by denudation.

The outer ridge and the lagoon mound are supposed to be consolidated within the area marked by vertical lines. After depression, the mean sea-level may be represented by the horizontal line 2 (fig. 10). The outward ridge is now brought within the destructive action of the breakers; its loose material will consequently be washed away, and may be driven over the reef into the lagoon, while the hard core will remain as the ridges and pinnacles of the ocean glacis. A fresh outer ridge will then be formed further inland behind the pinnacles left by the first (fig. 11).

In this way not only would the relation of the pinnacles to the outer ridge be fairly explained, but also one very singular character of the pinnacles, viz.: that they frequently occur as a linear series running parallel with the coast or even as a continuous ridge. It might be difficult to understand why denuded reef-rock should assume this form, but it readily follows if the pinnacles are merely remnants of the core of the outer ridge. If now we cast a glance over the section taken through the islet of Pava (fig. 12) we shall discover some very suggestive relations. The pinnacles form a ridge, which rises behind the nullipore rim, in much the usual way, but behind the pinnacles where we should expect to find the outer ridge, there is simply a broad, gently sloping platform of consolidated coral breccia, some 80 yards across, which ends against an accumulation of sand and small fragments of coral corresponding in composition and position with the lagoon-mound of other islets. Pava thus has the appearance that we might expect to be presented by an islet which had lost its former outer ridge without acquiring a new one. At the same time we must not omit to observe that the narrow ridge-like form of the pinnacles might also be explained by the action of erosion upon a stratified rock dipping seawards, as it does in this case; the outer face looking towards the ocean is a sea-cliff, the inner face looking in the opposite direction is a scarp, cut at right angles to the dip. Here the cliff and scarp have closely approached each other, hence the narrow ridge-like form; but instances may be observed in this northern region of the atoll where they still stand far more remote, bounding a comparatively broad platform. Sometimes also the scarp exists without a corresponding cliff.

If the features of the sea-ward face of the reef could be explained by a positive movement of the strand, we should next have to inquire whether the same explanation would apply to those bordering the lagoon. If, after submergence, any trace remained of the lagoon-mound we should expect to find its constituents, or the coarser part of them, arranged with a slope conformable to the ancient lagoon beach, *i.e.*, dipping lagoonwards, while as we have already seen the fragments in the consolidated platform and beach of the lagoon slope in the opposite direction. This, however, only proves that the lagoon cliffs and platform of hard rock are not the remains of an ancient lagoon mound, and this was a result to which we had previously been led; for we had already concluded that they represent the remains of a deposit, formed at a time when the waves washed *débris* from the ocean into the lagoon. They are indeed the oldest members of this deposit



Vertical height ½ m.m. = 1 Foot
Horizontal distances ½ m.m. = 1 Fathom.

Fig. 12.—Profiles obtained by levelling across the Islets.

1. Across Funafuti Islet, through the Mangrove Swamp.
2. Similar, but incomplete.
3. Through the same islet, taken through the site of the first boring, due east.
4. Through Pava Islet, from north to south.
5. Through Mateika, from east to west.
6. Through Funagogo, from east to west.

The thin continuous horizontal line on the left of the profiles, indicates the level of high tide, judged by its drift. The thin continuous line at the base of No. 5 indicates low-tide level, the dotted line above that of high tide.

or series of deposits; the material of the pinnacles being, on this hypothesis, the youngest now surviving. All that we can conclude from the facts we have just considered is that no remnants of the ancient lagoon mound are open to observation.* They may have been washed away simultaneously with the destruction of the ancient outer ridge, or they may be concealed under the modern lagoon mounds now existing. Instead of pursuing these speculations further we may proceed in search of additional evidence, and we turn first to the Mangrove Swamp. This interesting feature is situated at the "occiput" of the atoll and may be regarded as a widened extension of the central flat of Funafuti islet, lying within the bend, where the islet passes from a N.E.—S.W. to a N.W.—S.E. direction. A similar flexure separates the islets of Funafara and Telele further to the south. The eastern side of the swamp is sharply bounded by the inner slope of the ocean ridge, here rather steeper than usual; on the north and for a good part of its western margin it is bounded by low cliffs of consolidated coral breccia, and these are crowned in places by a beach of coral fragments and slabs of breccia, which lie within the arcaded roots of the surrounding mangrove trees. Some of the fragments of breccia seem to be of far too large a size to have been thrown into their present position by the waves of the water in the swamp, and thus suggest that the breccia platform may have undergone some erosion before the swamp was cut off from the ocean. At its southern end the Mangrove Swamp passes into the sandy flat of the Taro Swamp. Its northern arm is divided into two parts by a longitudinal ridge of hard coral breccia, which rises about 2 feet above the flat floor adjacent on either side; the western side of the arm is bounded by a cliff of coral breccia about 3 feet in height, the eastern half ends against the ocean-ridge and is covered by water for a great part of the day, affording a home to patches of close-growing madder-tinted algæ and delicate Renierid sponges of a bright rose tint.

The feature of chief interest in the swamp is afforded by its southern main portion, where a great part of the floor is formed by a dead coral reef, consisting almost wholly of two species, one a massive *Porites*, and the other *Heliopora cærulea*. The *Porites* projects as rounded flat-topped slabs or blocks, from 6 inches to a foot above the general level; these are surrounded by radiating growths of *Heliopora*, which may extend, in branching lamellæ and finger-shaped processes (figs. 13 and 14), for a distance of three or four yards from their origin. The clumps of *Porites* often attain a diameter of 4 feet, are frequently depressed in the centre, and traversed by more or less radiating channels, which owe their origin to included lamellæ of *Heliopora*, since removed by erosion. In many cases the *Heliopora* was the first of these corals to commence its growth; the *Porites* following, formed around the centre of the *Heliopora* system, and in rare cases outgrew the latter, so as to completely surround it; usually, however, the *Heliopora* increased more rapidly

* The position, however, of the ancient rock in the cliffs of the lagoon is scarcely consistent with the assumption of depression.

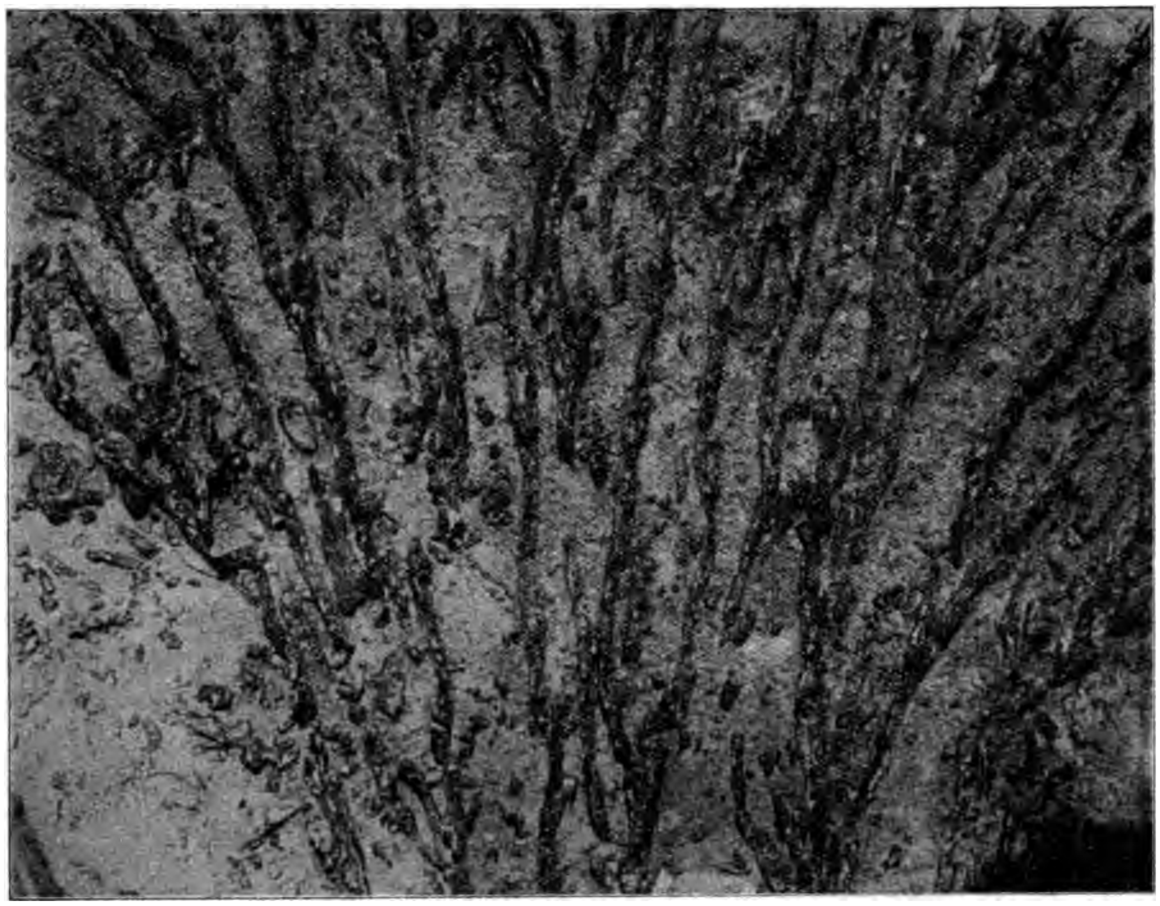


Fig. 13.—Reproduction of a photograph of *Heliopora cærulea*, as seen on the floor of the Mangrove Swamp.

than its companion, around which it forms a wide fringe (fig. 14). In many cases the surface of the *Porites*, which has been etched by the solvent action of sea water, reveals a distinct lamellar structure, running concentric with the margin.

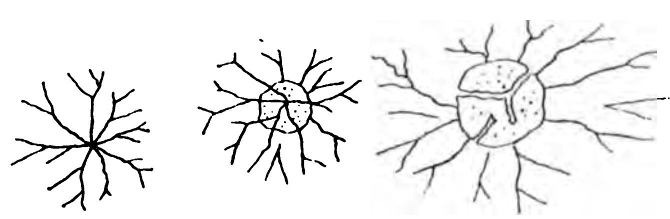


Fig. 14.—Diagrammatic sketch to illustrate the branching of *Heliopora* and its association with *Porites*.

The level tops of the *Porites* clumps look like a series of stepping-stones, about which the frayed ends of the *Heliopora* lamellæ stand like broken reeds, 6 inches above the floor of the swamp. For a great part of the day nearly the whole of the floor of the swamp lies bare and dry, but it is submerged several feet at high water; the sea gaining access to it through a number of transverse fissures, which are concealed from sight for the most part, but revealed as rounded pot holes in the

northern limb of the swamp. Down these the water may be seen descending as the tide falls, and that they communicate freely with the outer sea is shown by the fact that the body of a native child, drowned in the swamp, was afterwards found floating in the waves outside the reef. If these holes, as would appear to be the case, are the chief or the only means by which the sea can enter, it is possible that the high-water level in the swamp may stand a little below that of the open ocean.

The clumps of *Porites* are not, as we at first imagined, continued downwards into solid reef rock; on the contrary, they are isolated masses, which may be readily dislodged and overturned with the aid of a crowbar; between them, and filling the interstices of the *Heliopora* up to the general level of the floor of the swamp, is a fine silt abounding in foraminifera and dead molluscan shells.

The breccia which bounds a great part of the swamp extends in places to form its surface, lying in a thin encrusting sheet upon the *Heliopora* reef. It would thus appear that the reef is older than the breccia, and as this is but a part of the general hard crust which extends from ocean to lagoon, the reef is probably the oldest superficial feature of the atoll. It would seem to have concluded its growth before the present ocean-ridge and lagoon mound were in existence, and then to have become covered up with coral *débris*, which after consolidation was broken up to form the little beach now bordering the swamp on the landward side.

The flat summits of the *Porites* clumps are a suggestive feature, indicating an arrest of upward growth against a plain surface, such as would be afforded by the level of low water. Corals with similarly flat summits may be seen at present living in the lagoon, where it is evident that on reaching the low-water level they have ceased to grow upwards, but have extended laterally and again upwards to low-water level till a flat tabular form has been acquired (fig. 15).

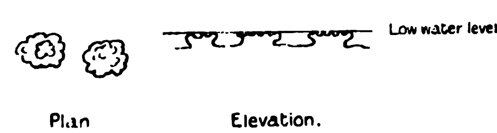


Fig. 15.—Diagram to illustrate the flat summits of corals which have grown up to the low-water level of the lagoon.

If it be admitted that the surface of the *Porites* clumps marks an ancient level of low water, then it obviously becomes a problem of extreme interest to compare this level with that of the existing sea. Accordingly, with the assistance of Mr. PAYNE, the boatswain, and a crew of seamen, I made two sets of measurements across the dead coral reef and the swamp from the lagoon beach to the ocean. These gave concordant results, and showed that the summits of the *Porites* clumps now stand 1 foot 4 inches above mean tidal level, *i.e.*, 4 feet 6 inches above low water at spring tides or 3 feet 9 inches above low water at neap tides. I therefore concluded that a change of sea-level in a negative direction to the extent of about 4 feet had occurred over the site of the Mangrove Swamp since the growth of its ancient reef. It is

scarcely likely that this change has been merely local and confined to this spot; had its amount proved to be slight, explanations based on possible alterations in the direction of waves or currents, or on a possible difference between low-tide level in the sea and the lagoon might have been offered for consideration; as it is we seem driven to the admission that a general elevation of the atoll or fall of the sea-level must have occurred since the *Heliopora* reef was in active growth.

The level summits of the *Porites* clumps have been regarded as marking a once-existing level of low tide; this is a minimum limit, for they may not have reached so high; it is very unlikely they grew higher. Abruptly succeeding them are the breccia beds, evidently formed under very different conditions, such as might be brought about by a change of sea level. These beds are very difficult to explain, but the evidence of the Taiisale reef seems to preclude an appeal to depression, and we are led to consider the effect of slight elevation of the atoll; a large elevation being equally precluded by the evidence of the Taiisale reef. At the close of the Taiisale period we imagine that the atoll was wholly submerged, and no ocean ridge nor lagoon mound was in existence. An elevation by which the mean-tide level became the low-tide level would expose the outer portion of the reef to the destructive action of the breakers, which, tearing off corals and coral fragments, would drive them across the inner portion of the reef into the lagoon, where they would accumulate in a low bank, and this would increase by continual accretion seawards till the waves had piled up a bank of breccia broad enough to present sufficient resistance to their further advance over the reef. The final stage might even have been the growth of an ocean ridge.

The formation of the breccia beds would thus depend on a nice balance between erosion and deposition, and might have occurred at a time when the summits of the *Porites* clumps corresponded with mean-tide level; a further slight elevation would then appear to have followed, raising the atoll about 1 or 2 feet; the breccia beds thus became exposed to marine erosion, but the resulting fragments, partly as a result of its increment in height, could no longer be everywhere driven across the whole breadth of the reef, but accumulated, along with material contributed by growing corals, to form the ocean ridge. The pinnacles and pinnacle ridges of the outer glacis are remnants of the breccia beds, and their form and disposition are to be explained as the result of marine erosion acting upon beds having a seaward dip, as already suggested in discussing the islet of Pava. They are now the chief irregularities on a slope of maximum stability, worn by the waves during a stationary period into a curve best fitted to resist their onslaught. This and the existence of the living breakwater afforded by the nullipore rim will explain the surprising smallness of the amount of destruction* at present accomplished on the reef by the great waves of the Pacific Ocean.

* This was a frequent source of surprise. During a windy night one would often be kept awake by the incessant thunder of the surf upon the outer beach, and it was difficult to resist the impression that the island was being washed away. On visiting the reef in the morning one expected to find the beach

In the hope of obtaining further information bearing on the question of a supposed change of level, I commenced to level across some of the islets in different parts of the reef; and I greatly regret that the idea of doing so did not occur to me earlier, for soon after the work was begun our second boring came to an end, and our stay upon the island was unexpectedly shortened. This was the more unfortunate as I had no previous experience in the use of the theodolite, and was only just beginning to discover the pitfalls that beset a levelling survey, when the time arrived for our departure; I should have liked to have been able to repeat my observations and to have reduced them all to the level of the tide-mark, which was engraved upon the Church shortly before we left; it would have been of interest also to compare the tide-level of the ocean with that of the lagoon, which might readily have been accomplished by levelling from one to the other, and then back again. The profiles of those islets which were levelled across are represented in fig. 12 (see p. 19).

Mateika presents features of especial interest; its lagoon mound is of unusual height, and, on surmounting its steep slope of loose sand on the lagoon side, a gently-sloping plain is reached which ends against a low cliff cut in horizontally stratified foraminiferal sandstone. Slabs of this rock lie at the foot of the cliff, and we are irresistibly reminded of a raised beach. On levelling across, the marks left on the sandy lagoon slope by the waves at high water were found at the unusual height of 9 feet 9 inches above low water, and the foot of the inner cliff stands at 8 feet 4 inches, or more than 1 foot below the high-water marks; the plain at its base may therefore represent a high-water terrace, and the sand ridge on its lagoon side may be a temporary feature liable to be removed at any time and again piled up in accordance with changes in the direction of the wind. The consolidated state of the sandstone exposed on the cliff is not so readily accounted for. I do not understand it, and forbear from speculation.

Another and remarkable instance of an islet bounded on the lagoon side by vertical cliffs of nearly horizontal consolidated beds is furnished by Amatuku (fig. 16). They are represented on the chart as rising 5 feet above high-water springs.

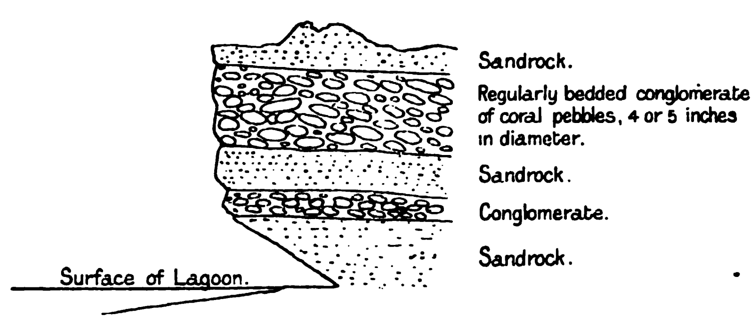


Fig. 16.—Diagrammatic section through the lagoon-cliff of Amatuku.

in ruins, and with astonishment found the sun shining on a scene unchanged. A rare fragment of coral tossed on to the strand, here and there an upturned slab of coral breccia, and that was all; the waves on the English coast might have accomplished more.

In places they are undercut and fallen fragments lie on the lagoon platform. The dip of the beds is a few degrees (3° to 4°) to the W.N.W. They consist of alternating sandstone and conglomerate, the latter formed of smooth, rounded pebbles of coral, generally about one inch in diameter, but frequently as much as 4 or 5 inches, and sometimes even 6 inches to a foot. Slabs and irregular fragments of coral are occasionally present. The smaller coral pebbles present an opaque white chalk-like appearance. The cementing substance of these beds, which is more abundant in some layers than others, has a reddish-brown colour and contains, according to an analysis, which Professor JUDD kindly had made for me, as much as 25 per cent. of calcium phosphate with some organic colouring matter. It coats round the pebbles as a thin layer formed of many concentric lamellæ, and extends from them into the interstices in tubular processes and irregular minute nodules which form a loose, spongy aggregate. On solution in hydrochloric acid a residue consisting of vegetable tissue sometimes remains behind.

The perplexity which has attended all my endeavours to explain the consolidation of superficial deposits on the atoll is dispelled in this case by the character of the cement, which probably owes its origin to the guano of sea-fowl, and has been deposited by rain-water percolating through loose sand and pebbles, standing above sea-level, and most likely above saturation level. The sandstone of Mateika is also of a reddish colour and may have been cemented in the same manner; but whether this be so or not, it is clear that in the case of Amatuku consolidation is far from suggesting a negative movement of the strand. It is difficult, however, to account for the alternation of nearly horizontal sand and pebble beds, without assuming that they were laid down under water, and this would involve a subsequent change in the relative level of land and sea. The "phosphates" present in these beds may possess some slight economic value; at any rate they might be used with advantage by the native population, as a contribution to the manure which they are in the habit of applying to the bananas of the Taro Swamp.

The levellings across the islets revealed nothing inconsistent with that negative movement of the strand, of which certain evidence seemed to be afforded by the *Heliopora* reef; but a doubt still remains in my mind as regards the structure of the pinnacles of the outer glacis; their base is, I feel sure, formed by the breccia beds, but their upper portion seems, in some cases at least, to consist of coral growths in place. If this should prove to be the case, the course of events during the later history of the atoll would have been more complicated than we have supposed, for we should be able to distinguish four periods, each corresponding to a change of sea-level, as follows:—

1. Taiisale period	Sea-level	relatively higher.
2. Breccia beds	„	lower than 1.
3. Coral growth of pinnacles .	„	higher than 2.
4. Existing reef	„	lower than 3.

In this connection a quotation from DARWIN may be apposite; he says*—"I have referred to these possibilities merely to show how difficult it must ever be to judge whether low coral formations have really been raised to a height of only two or three feet, as DANA believes to have been the case with several groups of atolls. To me it seems more probable that all the above-mentioned appearances merely indicate that the atolls in question have long remained at the same level." If, however, the conclusion arrived at by so excellent an observer as Professor DANA should hereafter be confirmed, the question will arise, seeing how immense an area has been thus affected, whether those geologists are not right who believe that the level of the ocean is subject to secular changes from astronomical causes.†

A possible cause affecting some of the superficial features of the atoll may be briefly noticed. We have already seen that both our borings revealed for a considerable distance downwards the existence of loose unconsolidated sand and coral *débris*, and it is not a little remarkable that material so little aggregated should be able to sustain itself in slopes of as much as 80°, such as occur between 36 and 129 fathoms on the flanks of Funafuti. The possibility of submarine slips naturally suggests itself, and a giving way of the reef, such as would precede a fall, seems to be indicated by a long continuous crack, which I observed traversing the hard seaward platform of Funafuti islet for a distance of about a hundred yards, and in a direction parallel to the coast. It is sharply cut and very narrow, never attaining, so far as I remember, a width of quite an inch. DARWIN, however, has an account of others still wider which are met with in the Caroline Islands, his words are‡ "on Oulleay Atoll, . . . , Admiral LUTKÉ informs me that he observed several straight fissures about a foot in

* 'Coral Reefs,' p. 173, 3rd edition.

† If the four stages, which we have suggested, really did occur in the history of Funafuti, they might very well be correlated with such movements of the ocean level as we should have expected on *à priori* grounds to have occurred in tropical regions during the Pleistocene period. The accumulation of ice about the polar regions during the glacial episode would seem almost necessarily to have brought about a lowering of the sea-level in the tropics, and if it did we might distinguish four different levels as having existed in these regions during Pleistocene times; they would have been as follows:—(*a*) Pre-glacial period, sea-level relatively higher; (*b*) glacial period, sea-level relatively lower; (*c*) genial period, sea-level relatively higher; (*d*) present period, sea-level relatively lower. The existence of a genial period separating the glacial from our own times is indicated by the marine faunas of post-glacial deposits found both in the Mediterranean basin and off our own shores. It will be seen that a close parallelism may be drawn between the four periods of sea-level as indicated by the atoll and as deduced from changes of climate; but this parallelism depends on the nature of the pinnacles of the glacis; if the summits of these should be found to consist not of corals in the position of growth, but simply of coral breccia, then the supposed parallelism will disappear, and we shall have to conclude either that the Taiisale period corresponds to the last genial episode which has affected our planet—and in this there would appear to be nothing improbable; or that the atoll affords no evidence either for or against the doctrine of the association of changes of ocean level with those of terrestrial climate; it would then follow that those changes of level which we have described must be explained in some other way, and most likely by movements of the atoll itself.

‡ *Op. cit.*, p. 132.

width, running for some hundred yards obliquely across the whole width of the reef. Fissures indicate a stretching of the earth's crust."

Neither in Funafuti, nor apparently in the Oulleay Atoll, do the fissures pass into faults; should they do so, and a downthrow occur on the seaward side, the curve of stability which now characterises the ocean beach of the atolls would be destroyed, and the sea would make inroads on the land, which would almost certainly lead to a redistribution of all superficial deposits in the vicinity. The effects, however, would be limited within a narrow area, and submarine slips cannot be appealed to as an explanation of quite general characters, such as those presented by the breccia beds and pinnacles. In this connection attention may be again directed to the very steep slopes, sometimes amounting to 80°, already mentioned. These can scarcely exist in loose material; submarine cliffs 300 feet high, and nearly vertical, must surely correspond with hard rock. The steepest cliff, that just mentioned, begins to descend at a depth of 450 feet, but some fairly steep slopes commence at 300 feet, and some 90 feet in height at 60 feet; hence, since our first bore-hole exceeded 60 feet in depth without passing through thick limestone, it would appear that the hard rock suggested by these outer steep slopes is not to be correlated with depth; it is more probably a feature of the outer reef, which consequently may possess a very different structure to that part which is accessible to bore-holes. By the nature of the case a bore-hole sunk, however near to the sea-margin, must enter the ground at some distance from the growing reef and become the more remote from this the deeper it descends, while at the same time it will approach continually nearer the supposed site of lagoon deposits. Thus too much stress must not be laid on the unconsolidated character of the material met with in our bore-holes; the exterior of the atoll may be faced with solid limestone, which, like a retaining wall, may hold up the looser deposits within. These, though preserved from giving way on a large scale, may still be liable to a certain amount of subsidence, sufficient to account for the cracks which have been observed in the ocean glacis.

Our observations on the lagoon suggest that it is gradually filling up. The three chief rock-formers—corals, foraminifera, and calcareous algæ—abound in its waters. Its floor is rich in growing corals, which, as shown in the chart prepared by Captain FIELD, frequently form reefs rising nearly, and sometimes quite, to the level of low tides. On one of these, Te Akau Tuluaga, I landed, and found both dead and living corals at its margin, whilst its surface was covered with sand and coral fragments. This reef seems to have grown noticeably in recent times, for Mr. O'BRIEN, the white trader on the island, informed me that when he first knew it its surface was 3 or 4 feet below low-tide level. But the reefs shown on the chart represent only a fraction of the coral which flourishes on the floor. On the western side (within the "nose" of the atoll) is a perfect garden of corals in luxuriant growth, and at various places near the shore corals may be seen extending in broad fields from the water's edge towards the depths. On the leeward side of the lagoon, opposite the site of the

first boring, were numerous reefs, from which we obtained many living corals, mostly of similar species to those growing in the outer sea, and though the upper surfaces of these reefs exposed at low tide were dead, their sides were completely covered with living forms, a fact to which I can bear most positive witness, since I have swum round them for a considerable distance at a depth of 4 or 5 feet under water, a feat to which I was frequently tempted by the extreme beauty of the spectacle afforded by the exquisite and vivid tints of the extended coral polyps.

The calcareous algæ are chiefly represented by *Halimeda*, which was brought up by most of the soundings, and sometimes filled the net used for dredging. During the whole of one afternoon which I spent with the sounding party under Mr. PAYNE, the boatswain, I noticed *Halimeda* adherent to the armature of the lead nearly every time it was brought up. Foraminifera abound, and constitute the larger part of the sand of the lagoon mounds. The sand in the "neck" (Te Ava uni uni) of the atoll is chiefly composed of them, as also is that of the sandy beaches, which extend for 100 yards or so into the lagoon. The growth of these organisms would appear to be rapid, for the natives informed us, and Mr. O'BRIEN, the white trader, confirmed their statement, that twenty years ago the lagoon opposite the Mission House was 14 or 15 feet deep, where now it is filled up with sand nearly to the level of the beach. Evidence of a similar rapid filling up of the lagoon of Nuku lai lai was given by COLLINS, the white trader on that atoll.

The sand of the beach is constantly shifting under the action of the winds. Pava and Fualifeke, shown as separate islets on the chart, are said to be joined together after the prevalence of westerly winds, which sweep the sand to the north and south, while easterly winds drive it on to Fualopa. The spot on which our "fale," or native house, stood is sometimes buried under sand by a westerly gale. Notwithstanding the large contribution of organic sand which the lagoon is periodically making to the land, it is itself, as we have seen, becoming levelled up in places by fresh accessions of this material.

Note.

Samples of water were collected from the lagoon at different depths for chemical examination. Their analysis was most kindly undertaken by Professor J. EMERSON REYNOLDS, F.R.S. The results, for the samples collected in lat. 8° 26′ 36″ S., long. 178° 55′ 22″ E., are as follows:—

	Chlorine per litre.
Surface	19·60
Depth of one fathom	19·24
Depth of 30 fathoms	19·66

The CO_3 radical was determined in terms of CO_2, and proved to be:—

	Carbon dioxide per litre.
Surface	0·132
One fathom	0·132
30 fathoms	0·132

SECTION II.

REPORT ON METEOROLOGICAL OBSERVATIONS MADE AT FUNAFUTI.

By H. C. Russell, *C.M.G.*, *F.R.S.*

From a meteorological point of view Professor Sollas's stay on the island, extending over June and July, was much too short to give a complete idea of the climate, but it is interesting as an index of the climate of an island within 10° of the equator in the two winter months.

He was provided with a set of high-class thermometers, consisting of wet and dry bulb thermometers, with Kew certificates that they had no errors; also with a maximum, with an error of + 0°·2 Fahr. by Kew certificate, which has been applied, and a minimum without error. A shade was constructed by building a small hut with banana logs.

As will be seen by comparison with Fiji observations, it was a satisfactory one. The observations in June show that the temperature at 9 A.M. ranged from 89°·8 Fahr. on the 11th to 76°·5 on the 16th. The cool days were cloudy ones. The maximum temperature, 94°·0, was reached on the 11th and 12th, and the lowest maximum, 81°·5, on the 6th; the lowest temperature at night was 74°·3 on the 22nd. The greatest range of temperature on any day was 16°·7, *i.e.*, from 91°·0 to 74°·3 on the 22nd.

The average 9 A.M. temperature was 83°·8 in June, and 83°·4 in July, and the highest in July was 88°·3 on the 28th and 30th, and the lowest was 77°·5 on the 17th. The maximum temperature ranged from 91°·5 to 78°, the mean 87°·4; in June it was from 94° to 81°·5, and the mean 88°·8. The minimum temperature ranged from 81° to 75°, and mean of maximum and minimum 82°·7, while in June the range was from 79°·6 to 74°·3, and the mean of maximum and minimum, or the mean shade temperature, 82°·8, so that practically the temperatures of these months were alike.

The greatest humidity in July was 94 per cent. on the 16th, corresponding with that in June, and the least 60 per cent.; that in June being 65 per cent., but the average for July is 78 per cent., compared with 79 per cent. in June.

The nearest point at which regular meteorological observations are taken is Suva, Fiji, which is almost in the same longitude as Funafuti, and 8½° farther south, and, according to the experience in Australia and elsewhere, a place should be about 1° cooler for each degree of difference in latitude.

It will be seen in the tabular statement that the shade temperature at 9 A.M. in June was 7° higher, and in July 8°·5 higher than at Fiji, using for Fiji not the temperature of the corresponding months in 1896, which were not available, but the average of these months for the past nine years.

Using the same data for the maximum and minimum temperature at Fiji, it appears that at Funafuti the maximum temperature was, in June 7°·6, and in July 7°·6 hotter than Fiji, and the minimum in June 6°·9, and in July 9°·5 hotter than Fiji.

Hot as the climate undoubtedly is, the most oppressing part of it is the extreme humidity, which approached saturation on many days, and maintained throughout June an average relative humidity of 79 per cent., and in July 78 per cent.; and this with the shade temperature many days over 90°, and averaging for June 88°·8, and for July 87°·4.

These conditions are enervating to the European accustomed to more bracing climes, and are only endurable under the shelter of a large building, with the accessories of life for such a climate. If a physical exertion must be made, it is only possible by an exercise of will, which amounts to an effort, and one soon feels that a minimum of clothing, such as the natives wear, is the only rational dress.

METEOROLOGICAL Observations made at Funafuti (9 A.M. and 3 P.M.), June, 1896.

1896.	Dry bulb. Deg.	Dry bulb. Deg.	Wet bulb. Deg.	Wet bulb. Deg.	Humidity. Per cent.	Humidity. Per cent.	Max. temp. Deg.	Daily range. Deg.	Min. temp. Deg.	Clouds 0–10*.	Clouds 0–10.*
June	9 A.M.	3 P.M.	9 A.M.	3 P.M.	9 A.M.	3 P.M.				9 A.M.	3 P.M.
1	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—
3	—	82·0	—	73·5	—	62	—	—	—	—	—
4	83·0	86·0	80·0	80·3	85	73	88·8	11·3	77·5	—	5
5	81·0	85·3	79·0	80·0	90	75	87·0	12·0	75·0	9	8
6	78·0	81·8	76·0	73·0	89	62	81·5	5·5	76·0	10	9
7	81·5	87·0	76·5	79·5	76	67	91·5	16·0	75·5	8	3
8	77·0	78·5	75·3	76·0	91	87	88·5	14·0	74·5	—	10
9	88·0	88·0	81·5	81·0	71	69	91·5	16·5	75·0	5	2
10	85·0	87·5	80·5	81·0	78	71	91·0	12·5	78·5	3	3
11	89·8	90·3	81·8	81·5	65	63	94·0	18·0	76·0	2	3
12	88·0	90·0	80·0	81·5	65	64	94·0	15·0	79·0	2	3
13	87·5	88·5	81·0	81·5	71	69	93·0	14·0	79·0	2	3
14	80·8	82·0	79·0	79·5	91	88	86·0	9·5	76·5	8	6
15	83·3	87·8	79·5	80·5	81	68	89·3	12·3	77·0	3	4
16	76·5	83·8	75·5	78·0	94	73	85·5	10·5	75·0	10	3
17	84·3	81·0	79·8	78·0	78	85	86·0	9·5	76·5	7	—
18	—†	81·0	—†	79·0	—†	90	—†	—†	—†	—†	10
19	84·3	89·8	80·5	82·8	81	69	92·3	16·3	76·0	5	1
20	87·0	86·0	82·2	81·0	77	76	89·0	11·0	78·0	5	—
21	81·0	87·0	79·2	81·0	90	73	89·0	12·5	76·5	9	4
22	86·5	81·3	82·0	80·0	78	94	91·0	16·7	74·3	4	5
23	85·5	84·0	80·0	78·5	74	74	89·5	9·9	79·6	3	3
24	83·0	84·0	77·8	78·5	75	74	88·5	9·5	79·0	4	9
25	85·0	86·5	77·3	80·5	65	72	90·0	14·5	75·5	—	—
26	86·0	88·0	79·3	80·0	69	65	91·3	13·8	77·5	—	1
27	83·5	86·5	79·8	81·0	81	74	88·3	12·3	76·0	2	8
28	84·0	80·5	80·0	78·0	80	76	85·0	8·7	76·3	3	9
29	84·0	82·5	81·0	78·3	85	79	87·5	10·2	75·3	3	4
30	85·0	85·5	80·0	81·5	76	80	89·0	10·5	78·5	4	—
Means.	83·8	85·1	79·4	79·5	79·0	74	88·8	12·1	76·7	5	5
Suva, Fiji	76·8	—	72·0	—	73·0	—	81·2	11·4	69·8	4·6	—
Differences	7·0	—	7·4	—	6·0	—	7·6	0·7	6·9	0·4	—

* Clear sky is indicated in the last two columns of the above table by 0; entirely overcast by 10.

† No observations.

Meteorological Observations made at Funafuti (9 A.M. and 3 P.M.), July, 1896.

1896.	Dry bulb. Deg.	Dry bulb. Deg.	Wet bulb. Deg.	Wet bulb. Deg.	Humidity. Per cent.	Humidity. Per cent.	Max. temp. Deg.	Daily range. Deg.	Min. temp. Deg.	Clouds 0–10*.	Clouds 0–10*.
July	9 A.M.	3 P.M.	9 A.M.	3 P.M.	9 A.M.	3 P.M.				9 A.M.	3 P.M.
1	85·3	87·5	78·8	81·0	70	71	91·0	10·5	80·5	4	2
2	86·0	83·0	80·5	79·0	74	80	90·0	13·0	77·0	5	3
3	85·0	88·5	80·0	81·5	76	69	91·5	12·5	79·0	2	2
4	86·5	89·3	80·0	81·8	70	67	91·3	13·3	78·0	1	—
5	84·8	88·0	79·5	80·0	75	65	90·5	13·7	76·8	9	4
6	80·5	80·0	78·0	78·0	88	90	85·0	8·0	77·0	10	10
7	78·3	79·5	77·3	77·0	94	88	80·0	4·5	75·5	10	10
8	81·8	85·8	77·5	78·5	79	67	87·0	10·0	77·0	9	3
9	84·5	87·0	78·0	79·0	70	65	90·0	12·0	78·0	5	2
10	86·0	88·3	79·2	80·3	69	65	90·0	11·0	79·0	3	—
11	84·3	80·8	79·0	78·0	75	86	85·5	5·5	80·0	9	4
12	79·0	84·8	78·3	80·0	97	77	87·5	10·0	77·5	10	5
13	79·3	86·0	73·3	82·0	71	80	87·0	10·5	76·5	9	6
14	85·5	85·5	81·5	81·5	80	80	89·5	8·5	81·0	4	8
15	81·0	83·0	78·5	79·0	87	89	86·5	11·0	75·5	9	—
16	83·0	89·5	79·0	81·0	80	64	87·0	10·0	77·0	4	2
17	77·5	79·0	77·0	77·0	98	90	80·0	2·0	78·0	10	10
18	77·5	78·0	77·3	77·5	99	97	79·0	4·0	75·0	10	10
19	81·3	80·5	77·5	76·0	81	78	85·0	9·0	76·0	10	10
20	82·5	78·0	73·5	76·0	60	89	86·5	7·5	79·0	9	10
21	78·5	78·0	77·5	76·0	94	89	78·0	0·7	77·3	10	10
22	85·0	—	80·5	—	78	—	85·5	9·0	76·5	3	—
23	86·0	87·0	80·5	80·5	74	71	88·5	9·5	79·0	3	3
24	84·0	84·0	78·8	80·0	75	80	89·0	11·5	77·5	2	4
25	85·9	87·0	81·5	82·3	78	78	89·8	12·3	77·5	3	3
26	85·8	84·4	81·0	79·8	77	77	87·5	9·2	78·3	4	6
27	82·5	88·3	78·5	81·0	80	68	89·8	10·8	79·0	9	1
28	88·3	86·0	81·8	81·0	71	76	91·0	11·0	80·0	2	0
29	87·8	87·8	81·3	81·8	71	73	91·0	11·0	80·0	—	3
30	88·3	88·8	82·3	82·3	73	71	91·5	12·0	79·5	4	4
31	—	—	—	—	—	—	—	—	—	—	—
Means	83·4	84·6	78·9	79·6	78	76	87·4	9·5	77·9	6	5
Suva, Fiji	74·9	—	70·0	—	76·0	—	80·1	11·7	68·4	4·4	—
Differences	8·5	—	8·9	—	2·0	—	7·3	2·2	9·5	1·6	—

* Clear sky is indicated in the last two columns of the above table by 0; entirely overcast by 10.

SECTION III.

REPORT ON THE RESULTS OF THE MAGNETIC SURVEY OF FUNAFUTI ATOLL BY THE OFFICERS OF H.M.S. "PENGUIN," 1896.*

By CAPTAIN E. W. CREAK, *R.N.*, *F.R.S.*

THE following extract from the instructions for the magnetic survey of Funafuti Atoll forms the keynote to the objects to be attained, and the subsequent conduct of the observations made there: "A magnetic survey of Funafuti is considered to be of importance not only in the interests of terrestrial magnetism, but in its bearing upon the geological investigation to be made there."

Previously to the "Penguin's" visit our acquaintance with the magnetic elements at Funafuti was confined to a fairly accurate knowledge of the declination, an element which can be easily obtained with sufficient precision by our ships equipped with the ordinary instruments of navigation. The inclination and horizontal force were only approximately known, being deduced from observations made some hundreds of miles distant. There was, consequently, ample need for observation.

A reference to the accompanying maps (p. 34) shows that the numerous islets of the atoll surround a large expanse of water, extending about 13 miles in a north and south direction, and 9 miles in breadth at its widest part, and studded with numerous coral reefs. It was, therefore, important that this large area, in which possible local magnetic disturbance might be found, should not be neglected. Hence the supply of the Fox dip and intensity apparatus for observations on a raft capable of being moved to any part of lagoon.

The following is a list of the instruments employed in the survey :—

1. For absolute observations on land :

   Unifilar magnetometer, No. 25.
   Barrow's dip circle, No. 34.

2. For relative observations on the raft :

   Fox dip and intensity apparatus.

3. For differential observations of the declination :

   A portable differential magnetometer.

* Forwarded to Sir W. J. L. WHARTON, K.C.B., F.R.S, Hydrographer to the Admiralty.

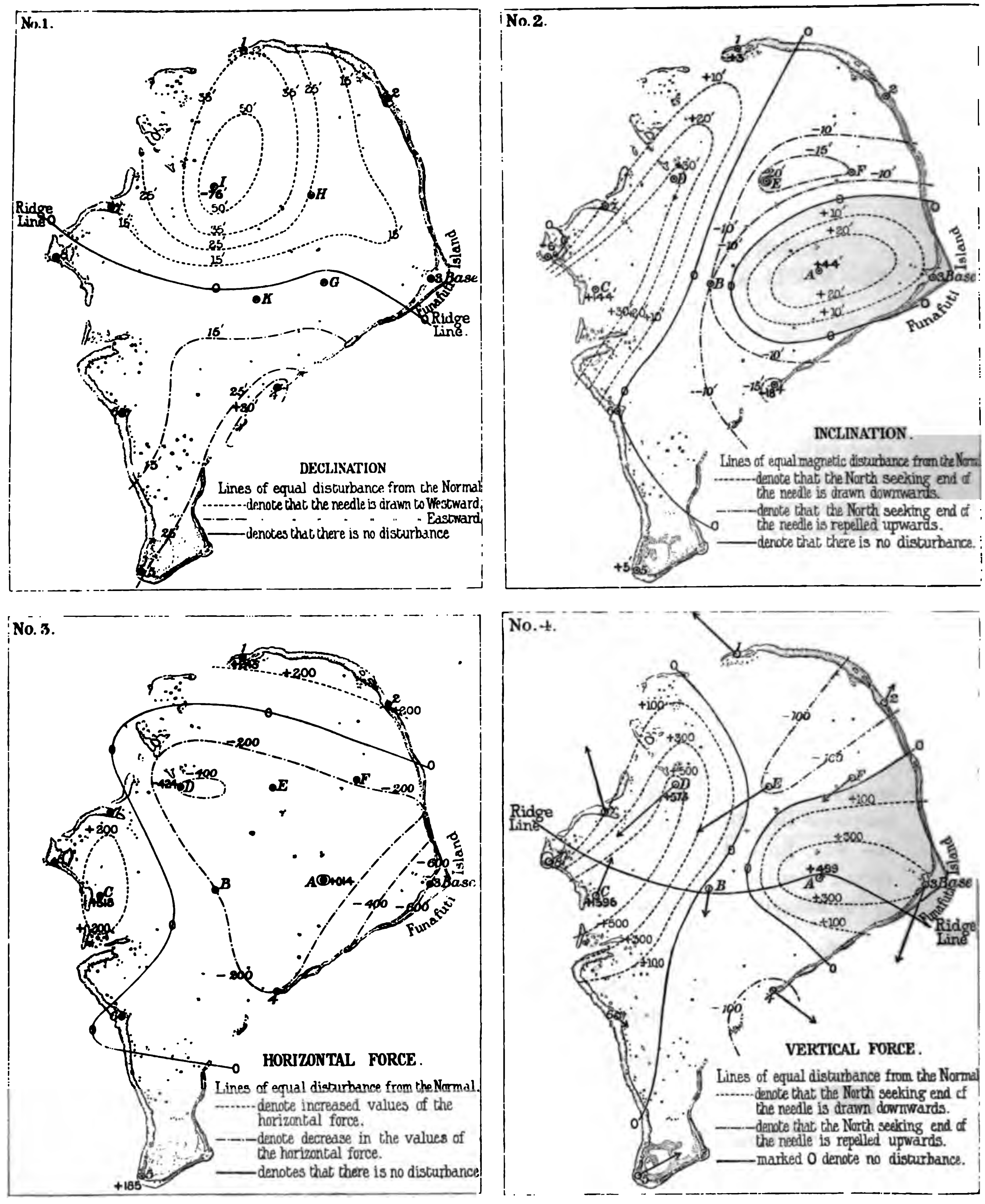


Chart of Magnetic Disturbances.

Base Station.

At Funafuti, a quarter of a mile south of the Mission House, a base station was selected. Here observations with the absolute instruments were made at the commencement and towards the close of the series. The differential declination magnetometer was also set up, and hourly observations made. The base observations with the Fox apparatus were also made here, including the formation of a table of equivalent weights.

Diurnal Variation of the Declination.

Although some difficulties arose with the observation of the differential magnetometer from the instability of the stands upon which the instruments were mounted, and from suspension threads breaking, so much care was taken in constantly verifying the zero, that the following results may be accepted as a very close approximation to the truth :—

Extreme range : June, 3′ 25″ ; July, 2′ 23″.

The needle attained its extreme deflection—

June : East extreme, 6.30 A.M. ; west extreme, 1.0 P.M. ; 2nd east extreme, 7.0 P.M.
July : East extreme, 6.30 A.M. ; west extreme, noon ; 2nd east extreme, 7.0 P.M.

The general characteristics of the diurnal variation therefore approach those observed at Kew for example during the summer months, and are as might be expected in south latitude during the three months when the winter solstice occurs.

Normal Values.

One great object of the magnetic survey was to ascertain if any local magnetic disturbance existed, and, if observed, to point out to the geologists the areas of greatest disturbance as those where rocks might be nearest the surface and be most eligible for borings. The question then arose as to how the best normal values could be determined in such an isolated spot. For the declination a close approximation was obtained by swinging the ship in deep water both to the northward and southward of the island, the effects of the iron in the ship and possible disturbance of the land being thus eliminated. In the case of the inclination and force the vertical disturbing force caused by the iron in the ship was a bar to similar results, swinging the ship being obviously of no avail.

The mean of the absolute observations at the land stations was therefore taken as normal, the declination having the valuable check of the swinging before mentioned.

Disturbances from the Normal.

In Table I. the disturbances from the normal are given, the force being expressed in terms of C.G.S. units = 0·00001.

These results form the elements from which the Charts 1, 2, 3, 4 (p. 34) are compiled.

Commencing with the disturbances of the declination on Chart 1, it will be observed that principal disturbance occurs at station I, towards the western side of the lagoon amounting to 76′, the needle being deflected to the westward.

Again, there is a belt of little or no disturbance more nearly defined by the black ridge line extending across the east and west axis of the atoll.

The whole field of disturbance of this element in the north and south direction appears to extend from to about 11 miles north of the ridge line and 14 miles to south of it; to the eastward and westward of the atoll the field is indeterminate for want of observation.

On the whole, the chart of the declination disturbances may be considered as accurate, the observations over the lagoon having been carefully taken on board the ship, which gave a steady platform. The observations on land were further corrected for the diurnal variation.

Turning to the vertical force disturbances on Chart 4, the greatest values observed occur at C, D and A, taking them in order of values.

Taking next the direction of the arrows in the lagoon showing the direction and amount of the horizontal disturbance, it will be seen that they point to the origin of the principal disturbances as being due to at least two centres ot force situated below the ridge line.

It will be remarked that the principal foci of disturbance at C, D, A, bear the plus sign, denoting that the north seeking end of the needle is drawn downwards, and also from the surrounding values of the same sign that the amount of disturbance of that nature is far in excess of that repelling the needle as shown by values bearing the minus sign.

This is the more remarkable, as heretofore observation has generally shown that in islands situated in regions of minus vertical force the reverse order has been the rule, and minus vertical force disturbances have largely exceeded those with the plus sign.

Charts 2 and 3 showing lines of equal disturbance of the inclination and horizontal force do not require any special remarks.

Before concluding this account of the disturbances, it is necessary to point out that although we may accept the observations on land at Funafuti Atoll as trustworthy, those of the inclination and force at the lagoon stations are much less so, having been taken on a raft in motion and with relative instruments. The general features of the disturbances may, however, be accepted as correct.

The regions of greatest disturbance were duly communicated to Professor DAVID

in time for the latest boring, but the latter was necessarily undertaken on the opposite side of the lagoon to that of the greatest magnetic disturbance, which is certainly a matter for regret.*

In conclusion, it may be remarked that the work which has produced such important results for the special objects for which it was undertaken has not assisted in throwing light upon the nature of the land causing the magnetic disturbances.

In Tables II. and III. will be found the results of the observations made both on land and afloat during the stay of the "Penguin" by Captain A. M. FIELD, R.N., and Lieutenant (now Commander) W. P. DAWSON, R.N.

TABLE I.—Disturbances from the Normal.

Station.	Declination.	Inclination.	Hor. force.	Vert. force.	Hor. force to North.	Hor. force to West.	Resultant disturbing force and angle.	
							Angle.	Force.
No. 1	−35′	+ 3′	+243	− 39	+314	+329	314°	455
„ 2	+ 3	− 5	+222	− 142	+120	− 67	29	138
„ 3	− 8	+ 7	−604	+ 296	−561	+203	200	596
„ 4	+33	− 18	−199	− 137	−232	−296	128	376
„ 5	+25	+ 5	+185	− 17	+146	−287	63	322
„ 6	+ 7	+ 1	− 52	+ 29	− 51	− 65	133	89
„ 7	−14	+ 13	+162	+ 99	+466	+121	345	482
„ 8	+ 8	− 6	+ 60	− 87	+ 60	− 83	54	103
† A	—	+ 41	+ 14	+ 499	+ 10	− 10	45	10
† B	—	− 9	−193	− 36	−190	+ 30	190	190
† C	—	+144	+318	+1596	+310	−130	23	340
† D	—	+ 34	−424	+ 573	−350	+430	231	560
† E	—	− 22	−382	− 137	−310	+490	238	580
† F	—	− 14	−179	− 077	−150	+210	235	260
‡ G	+ 4							
‡ H	−25							
‡ I	−76							
‡ K	+ 5							

* As the success of the boring in the lagoon depended chiefly on the mooring of H.M.S. "Porpoise" at a spot where she would be sheltered from wind and currents, it was considered prudent not to place the site for the first bore further from the main island than was consistent with the above requirements, at the same time the site was chosen as near as was practicable to the focus of the eastern region of magnetic disturbance.

Had time allowed after the completion of the first borings the ship would have been moved to the actual focus of the eastern region of magnetic disturbance, and a bore would have been attempted there also, but as the one week available for the whole work was entirely spent in mooring the ship and making the two bores at the first site, the proposal to bore at the focus had to be abandoned. The western region of magnetic disturbance was too exposed to risk boring there in the first instance.—T. W. E. D.

† These results were obtained from observations made on a wooden raft and are to be considered only approximate—the inclination disturbances to ± 10′, the hor. force to ± 100.

‡ These disturbances were obtained from observations made on board the ship in the lagoon and may be considered correct to ± 5′.

Table II.—Absolute Determinations at Land Stations.

Place of observation.	Date.	Time.	Declination.	Inclination or dip = θ. Date.	Needle.	Time.	θ.	Absolute horizontal force. Date.	Magnet.	Time.	H.
Pava. ⊙ 1.	1896.	h. m.	East.	1896.			S.	1896.		h. m.	C.G.S.
N. end of lagoon	June 2	10.45 A.M.	8° 30′·1	June 2	No. 3	11.0 A.M.	19° 29′·5	June 2	25 *a*	1.30 P.M.	0·3680
Lat. 8° 25′ 43″ S.	—	—	—		„ 4	Noon	19 32·2				
Long. 179° 7′ 40″ E.	—	—	—		„ 3	2.30 P.M.	19 31·6	—			—
Funafuti. ⊙ 2.	—	—			No. 3	10.15 A.M.	19° 38′·1				
N. extreme of islet	May 29	9.40 A.M.	9° 8′·3	May 29	„ 4	11.30 A.M.	19 37·7	May 29	25 *a*	1.30 P.M.	0·3678
Lat. 8° 26′ 54″ S.	—	—			„ 4	3.0 P.M.	19 39·3				
Long. 179° 10′ 48″ E.	—	—		—	„ 4	3.40 P.M.	19 40·3			—	
Funafuti. ⊙ 3											
S. of mission house	May 26	11.0 A.M.	8° 55′ 49″	May 27	No. 3	4.0 P.M.	19° 25′·8	May 27	25 *a*	2.30 P.M.	0·3595
Lat. 8° 31′ 17″ S.	„ 27	10.10 A.M.	8 55 53	„	„ 4	4.30 P.M.	19 27·5				
Long. 179° 12′ 23″ E.	June 25	9.30 A.M.	8 59 14	June 15	„ 3	11.0 A.M.	19 25·5	July 31	25 *a*	3.0 P.M.	0·3590
Magnetic base											
Funamanu. ⊙ 4.											
Islet on E. side of passage	May 5	4.10 P.M.	9° 38′ 2″	June 5	No. 3	1.30 P.M.	19° 50′·2	—			
Lat. 8° 33′ 56″ S.	—	—		„ 11	„ 3	4.30 P.M.	19 52·5	June 11	25 *a*	2.30 P.M.	0·3636
Long. 179° 8′ 30″ E.	—	—				—		—			
Avalau. ⊙ 5.											
Islet at S. end of lagoon	May 28	11.20 A.M.	9° 29′ 58″	May 28	No. 3	3.30 P.M.	19° 31′·7	May 28	25 *a*	1.0 P.M.	0·3674
Lat. 8° 28′ 30″ S.	—	—		„	„ 4	4.0 P.M.	19 26·0	—	—		
Long. 179° 5′ 12″	—	—					—	—			
Fuagea. ⊙ 6.											
Islet on W. side of lagoon	June 4	5.50 P.M.	9° 12′ 23″	June 4	No. 3	4.0 P.M.	19° 32′·7	June 4	25 *a*	1.15 P.M.	0·3650
Lat. 8° 34″ 35″ S.	—	—					—	—			
Long. 179° 4′ 37″ E.	—	—				—				—	
Fualopa. ⊙ 7.											
Islet on N.W. side of lagoon	June 1	10.10 A.M.	8° 51′ 12″	June 1	No. 3	11.30 A.M.	19° 21′·6	June 1	25 *a*	2.15 P.M.	0·3672
Lat. 8° 29′ 31″ S.	—	—	—	„	„ 4	11.0 A.M.	19 18·0		—	—	
Long. 179° 4′ 20″ E.	—	—	—			—				—	—
Fuafatu Island. ⊙ 8.											
Lat. 8° 30′ 47″ S.	July 10	10.20 A.M.	9° 13′ 0″	July 10	No. 3	3.45 P.M.	19° 40′·0	July 10	25 *a*	11.0 A.M.	0·3661
Long. 179° 3′ 6″ E.	—	—	—	—	—	—	—	—	—	—	—

TABLE III.—Observations made with the Relative Instruments on a Raft and on Board the Ship.

Date.	Station of raft.	Bearing and distance from Funafuti base.	Declination.	Inclination.	Horizontal force.	Depth of water in fathoms.
1896.	--	Funafuti base, S. of Mission House. Lat. 8° 31′ 17″ S. Long. 179° 12′ 23″ E.	--	Needle A.	C.G.S. units.	--
June 9	A	S. 88½° E. (true) 2′·67	–	18° 52′·5 S.	·3657	In 23 fms. sand and coral.
″	B	N. 89° E. ″ 5·43	—	19 43·0 ″	·3636	″ 23 ″ ″
″	C	N. 89° E. ″ 8·3	—	17 9·7 ″	·3687	″ 22 ″ ″
June 10	D	S. 68½° E. ″ 6·67	—	19 0·0 ″	·3613	″ 3 ″ ″
″	E	S. 58½° E. ″ 4·7	—	19 55·6 ″	·3617	″ 30 ″ ″
″	F	S. 35° E. ″ 3·16	—	19 47·5 ″	·3637	″ 22 ″ ″
July 9	G	S. 88½° E. ″ 2·67	9° 9′ E.	Observations obtained on board by swinging the ship.		—
″	H	S. 55° E. ″ 3·67	8 40 ″			—
″	I	S. 67¼° E. ″ 5·93	7 49 ″			—
″	K	N. 83¼° E. ″ 4·45	9 10 ″			—
July 13	North of lagoon	Lat. 8° 22′·0 S. Long. 179° 6′·0 E.	8 50 ″			Station N. of lagoon in 600 fms.
″	South of lagoon	Lat. 8° 45′·0 S. Long. 179° 4′·0 E.	9 11 ″			Station S. of lagoon in 150 to 500 fms.

SECTION IV.

NARRATIVE OF THE SECOND AND THIRD EXPEDITIONS.

By Professor T. W. EDGEWORTH DAVID, *B.A.*, *F.R.S.*

THE Funafuti Expedition of 1897 was the outcome chiefly of a sympathetic letter from Professor JUDD, with regard to the failure of the diamond-drill boring of 1896, in which he expressed the hope that some attempt might still be made to retrieve the failure. The Expedition of 1896, while successful in many ways, had broken down in precisely that branch for which we, in New South Wales, had held ourselves responsible, viz., the boring. We felt that it was due to Professor SOLLAS, and to those associated with him in the enterprise, to make good to them, if possible, that which the 1896 Expedition lacked, viz., a core of coral rock from the surface to a depth of 500 to 1000 feet. Without this obviously DARWIN'S wish to test the atoll question by boring to this depth could never be realised.

It may here be stated that the diamond-drill apparatus sent in 1896 was the best that the Colony could supply, and if the Funafuti rock had possessed the hardness and density of sandstone or granite or basalt, a depth of 500 to 1000 feet would probably have been attained in the time available. The apparatus, however, sent in 1896, was not capable of boring through alternating layers of hard cavernous coral rock and disintegrated materials, but was specially adapted for boring a material of sufficient compactness and strength to make it unnecessary to line the sides of the borehole with iron pipes. Professor SOLLAS had, indeed, supplied us with the report of Sir EDWARD BELCHER'S attempt to bore the coral rock at Hao. The depth attained, however, on that occasion was so insignificant that it gave us little information as to the nature of reef rock at some depth under an atoll. The bores in reef rock at Oahu in Sandwich Islands and at Key West, near Florida, were put down with percussion drills, which rendered it difficult to ascertain the exact character of the rock penetrated, though the general evidence was that the rock was fairly compact. Our knowledge of raised reef limestone in the Pacific led us to the same conclusion. This misapprehension of the true character of the reef rock to be encountered at Funafuti, led to the apparatus sent in 1896 being defective in the following respects:—(1) The supply of lining pipes was insufficient; (2) no steel shoes to screw on to the leading end of the lining pipes were sent; (3) no under-reamers constructed to project a strong stream of water from their under-surface were

sent. Our experience of 1897 showed that it was impossible for Professor SOLLAS, with a boring apparatus wanting in the above respects, to have bored deeper than he did. In view of our 1897 experience, we were surprised that it was found possible to bore, without an under-reamer, to a depth of over 100 feet in the reef rock of Funafuti, as was done by the Expedition of 1896.

Our boring experience in New South Wales in rocks other than reef rock has shown that the most difficult and costly type of rock to bore with a diamond drill is any cavernous variety, like vesicular basalt. The small cavities in such a rock cause much splintering of the diamonds and jarring of the diamond-drill machinery. When, however, as proved to be the case at Funafuti, the size of the cavities varies from a fraction of an inch up to over a foot or even several feet in diameter, and the larger of them are filled with running detritus, the difficulties of diamond drilling are immensely increased.

After the receipt of Professor JUDD'S letter, we consulted men experienced in diamond drilling as to our chances of success if we attempted another bore at Funafuti, but the hopes they held out were not encouraging. Mr. W. H. J. SLEE, however, the Government Superintendent of Diamond Drills, was confident that with proper precautions the work could be done, and at once promised his cordial support if the Government approved of the proposal. Professor ANDERSON STUART and I then attempted to raise the necessary funds. Mr. H. S. W. CRUMMER, the Hon. Secretary of the Royal Geographical Society of Australasia, co-operated, and the above Society, whose President, the Hon. PHILIP GIDLEY KING, was formerly a colleague of Darwin on H.M.S. "Beagle," rendered us valuable assistance. We laid our plans before Senator J. T. WALKER, with the result that, after a few weeks' consideration, Miss EADITH WALKER, of "Yaralla," Concord, Sydney, very generously subscribed £500 for the Expedition. The Expedition having now been brought well within the bounds of possibility, we approached the Government of New South Wales. The Premier, the Right Hon. G. H. REID, P.C., promised that the Government would support the undertaking, and the Hon. SYDNEY SMITH, the Minister for Mines, sanctioned the loan of one of the Government diamond drills. We now applied to the Royal Society of London for further pecuniary aid, to which they liberally responded, and meanwhile the late Mr. RALPH ABERCROMBY, the Meteorologist of Elizabeth Bay, Sydney, was good enough to subscribe £100 to the Expedition.

Preparations were now made for our departure. Special care was taken by Mr. J. S. LEIGH of the Diamond Drill Branch, in accordance with Mr. SLEE'S instructions, to see to the construction of a good type of under-reamer, and the securing of the manufacture of the best type of steel shoes for the lining pipes. Meanwhile I tried to secure the services of some of my Australian geological colleagues for the Expedition. Mr. C. C. BRITTLEBANK, of Myrniong, Victoria, who at first arranged to come with us, was eventually prevented, which was a serious loss to the

Expedition, but fortunately Mr. G. SWEET, F.G.S., of Melbourne, was able to join me. Later two of my University Students—Mr. W. G. WOOLNOUGH, B.Sc., F.G.S., and Mr. W. POOLE, B.E., F.G.S.—volunteered their services; these with my wife and myself and the contingent in charge of the diamond drill completed the party. The latter comprised the following:—J. HALL (foreman-in-charge); G. BURNS (assistant foreman); J. GARLAND (assistant foreman and artificer); J. DENT (assistant); E. A. HAMBLY (assistant); F. SMITH (assistant). We had hoped that Professor SOLLAS might be able to join us later, but unfortunately his work at the University of Oxford made that impossible.

In addition to the diamond drill, we got ready a small drill to be mounted on a wooden platform about 10 feet high, and to be driven by an oil engine. This was designed for boring at the small sand patch known as Te Akau Tuluaga, near the centre of the Funafuti Lagoon. We were informed, but the information proved to be erroneous, that this patch was an island a little above high water, in which case it would have been an ideal site for a bore. This small drill was designed by Mr. W. F. SMEETH, M.A., B.E., A.R.S.M., who was most useful and untiring in assisting me in the final preparations for the Expedition. We also provided ourselves with a strong new boat, 20 feet in length, which was purchased for us by the Hon. H. C. DANGAR and Professor ANDERSON STUART. Lastly, we had prepared the material for a corrugated iron shed. We originally intended sailing down from Sydney in the barque "Loongana," trading with the Gilbert and Ellice Islands, and had actually made provisional agreements for the freights and passages with her owners. She was, however, seriously delayed on her return journey from these islands, and as she was several weeks overdue, and June was already approaching, we had to devise some other means of transport to Funafuti. Eventually we arranged to go by the Union Company's s.s. "Taviuni" from Sydney to Suva, transhipping from that port in the same Company's coasting steamer "Maori." The cost, however, of this arrangement was far in excess of our original estimate, which was based on the tender of the owners of the "Loongana," and through want of funds it appeared, up to the day before the "Taviuni" actually sailed, that the whole Expedition would have to be indefinitely postponed. In this serious crisis Miss EADITH WALKER assisted us most handsomely by providing a loan of £400 (£150 of which she subsequently added as a donation to her original gift of £500).

Before our departure Mr. STANLEY GARDINER and also Mr. C. HEDLEY gave me much useful information; Professor LIVERSIDGE supplied Winchester quart bottles for obtaining samples of sea-water for analysis, Professor HASWELL a large toothed iron crown for dredging as well as a dredge, Mr. J. P. HILL a dredge, and Mr. R. ETHERIDGE, Junior, a dredge and tangle bar. Mr. J. H. MAIDEN, the Director of the Botanic Gardens, furnished material for botanical collecting, and Mr. H. C. RUSSELL, F.R.S., Director of the Sydney Observatory, supplied us with minimum thermometers. Mr. G. H. HALLIGAN, L.S., F.G.S., Government Hydro-

grapher, lent us (with the kind consent of the Hon. J. H. YOUNG, Minister for Works) several useful pieces of boring and dredging apparatus.

We left Sydney in the "Taviuni" at 1 A.M. on June 3rd, 1897, arriving at Suva on June 10th. The Hon. B. G. CORNEY, M.D., at once came on board, and informed us that through the kindness of Mr. E. W. KNOX and Mr. GEMMEL SMITH, of the Colonial Sugar Company, he had been able to arrange for a large punt, belonging to that Company, to come alongside the "Taviuni" for the purpose of "lightering" our gear and storing it until the s.s. "Maori" was ready to take it on board. This period of transhipment was a very anxious one, as we had over 200 packages of gear and stores (including one 3-ton boiler and one 1½-ton boiler) with over 1400 feet of boring rods and over 2000 feet of lining pipes. Mr. SWEET and Messrs. WOOLNOUGH and POOLE rendered excellent service in connection with the tallying of the gear and stores.

The "Maori" did not sail until June 15th, and in the interval Dr. and Mrs. CORNEY made our stay at Suva enjoyable and interesting. We visited under Dr. CORNEY's guidance the raised reef at Walu Bay, near Suva. The reef is about 45 feet in thickness, having at its base a conglomeratic bank of coarse waterworn pebbles of andesite, quartz-porphyry, and more rarely quartz-schist. The reef is capped by about 50 feet of soapstone (the well-known tuffaceous foraminiferal rock of Fiji), and rests on a similar formation. The base of this reef is approximately a little over 100 feet above sea-level. The Hon. A. M. T. DUNCAN had 73 tons of coal shipped for us on the "Maori," which, with the 63 tons already landed for us at Funafuti by s.s. "Archer," would raise our total coal supply available for the drill when Funafuti was reached to 136 tons.

The Hon. JAMES STUART, C.M.G., and the Commissioner for Works and Water Supply, Mr. JOHN BERRY, also rendered us kind services. Nothing, indeed, could have exceeded the kindness shown us by the Government as well as by personal friends in Fiji. We left Suva early on June 15th, Dr. CORNEY supplying us with a large quantity of bamboos, which at the time seemed superfluous, but which afterwards we were very thankful to have for rafting the boilers ashore and supplying poles for carrying the gear across the island.

We entered the circular reef of Weilagalala, and landed at the central island, afterwards the scene of Professor AGASSIZ's bore, on June 16th. We left the same day for Funafuti. The weather most of the way down was rainy and rough.

We arrived off Funafuti on Saturday, June 19th, sighting the atoll at 4 A.M. The night was clear and the morning star shone brightly. Captain MACLEAN having identified the white beacon on the south end of Funamanu, which marks the entrance to the Bua Bua Passage, we steered for it and were soon inside the Funafuti Lagoon, and with the help of the detailed chart kindly given me by Captain FIELD, R.N., we were able to steam right ahead to the main village, Fongafale, off which we anchored.

The official letter to the Tupu of Funafuti from the High Commissioner of the Western Pacific, Sir HENRY S. BERKELEY, having been duly presented, we landed, and an examination was at once made of the island near the village with a view to choosing a favourable spot for the diamond drill. The spot selected is shown on Plate 9 near Section 10 and also on Plate 19, and bears about N. 31° E. (magnetic) from the mission church, 450 yards distant.

Meanwhile, Captain MACLEAN made a raft, partly out of the bamboos given us by Dr. CORNEY, partly out of the timber belonging to the little drill, and native porters having been engaged, the work of unloading and landing the gear and carrying it across the island to the site for the drill camp was proceeded with at once, heavy rain falling towards evening. The next day, Sunday and the Diamond Jubilee Day of her late Majesty was kept as a day of rest for all hands. A Royal Salute was fired and the National Anthem sung. The following day, by dint of working from sunrise to after dark, all our material, including the coal, was landed in the midst of the heavy downpours of tropical rain, and the s.s. "Maori" left the island at daybreak the following morning (June 22). Mr. SWEET rendered very valuable service in the work of transporting the drill machinery, including the heavy boilers, across the island, and in erecting a commodious shed of corrugated iron for our stores.*

The diamond-drill men fixed their tents and water tanks and erected the derrick and drill, and on the eleventh day after our arrival at the island the Tupu turned on the steam and so started the drilling. The rock of the reef platform upon which we started boring was so tough that the drill was running for several hours without boring more than an inch or so. This, however, was partly due to the diamonds being inset rather too deeply into the soft-steel boring-crown.

Meanwhile having ascertained that the information given me in Sydney that there was a small island in the middle of the lagoon was wholly incorrect, there being nothing but a shoal, known as Te Akau Tuluaga, difficult of access from the village (about 5 miles distant), difficult too for landing gear and having a dangerous break over it during rough weather, I reluctantly decided to abandon the attempt to get a bore down with the little drill in the middle of the lagoon.

To this decision I was led by the consideration that the delay in erecting the staging and oil engine would have been very considerable. It would have been possible to work at the erecting of the drill only after half-tide at this shoal and then calm weather would have been essential. Every piece of machinery would have had to be taken by boat, and the wooden staging must have been towed in instalments. Each journey to and from the shoal would have meant 10 miles at

* This shed proved a great comfort and convenience during the whole of our visit, and we should strongly recommend any future expedition, going under conditions like ours, to provide themselves with a similar shed of galvanised iron roof and sides, with the timber of the framework ready cut to length and numbered so that it can be quickly fitted together.

least, the return journey having to be made in the teeth of the trade wind. It would, I estimated, have occupied fully a month to erect the staging and the machinery, and under the circumstances I questioned whether we should succeed in doing this satisfactorily at all in the time at our disposal. The cost of boat hire and labour hire too would have amounted to from £40 to £50, which was more than I could afford for the purpose, such small amount of cash as I had being reserved chiefly for dredging and drilling operations on the steep ocean face of the reef. It seemed best under the circumstances to try and get a bore down on the lagoon edge of the reef due west of the diamond-drill bore, with a view of ascertaining the dip, if any, of strata struck in the main bore.*

After hard work we succeeded in starting the little drill on the sixteenth day after our arrival. After passing through 7 feet of foraminiferal and *Halimeda* detritus we encountered a coarse coral shingle for about 2 feet, then a cavernous *Heliopora cærulea* reef-rock with the spaces between the branches partly filled in by a growth of *Lithothamnion*, a rock which is precisely similar to that penetrated at a similar depth by the diamond drill. The little drill was not intended for boring hard rock, as we had anticipated that the material of the supposed island at the middle of the lagoon would be soft. We tried boring with a bit which we armed with sapphires, but they proved much too brittle for boring the coral rock, splintering quickly along the cleavage planes. We then tried chips of steel files and succeeded in cutting through the coral rock for 16 feet with these, but the file chips soon had their cutting edges blunted and needed to be constantly replaced, which was laborious and wasted much time. We could, nevertheless, have bored much deeper by this means, if it had not been for (1) The very heavy silt which choked our bore-hole directly the pump stopped working, and (2) We had no under-reamer which would jet water from its under surface concurrently with the work of boring. Our under-reamer was one of the "ball" type, worked on the percussion principle, the favourite type used by artesian well drillers in New South Wales. As soon, however, as we drew up our boring rods and lowered the ball under-reamer to under ream the coral rock, we found that silt had risen in the bore-hole to a height of ten feet or more. We attempted to get rid of this silt with a sand pump, but as often as we withdrew the sand pump from the bore-hole fresh silt flowed in from the tortuous channels at the side. As all attempts to "monkey" our lining pipes through this hard coral rock failed, we were forced at last to abandon this small borehole at a depth of 25 feet.†

The following is the section obtained in the small bore:—Surface of bore about

* It may be here mentioned that it seems to Mr. HALLIGAN and myself that it would be quite possible and very desirable to put down a bore at Te Akau Tuluaga, but the drilling apparatus, and staging to carry it, should be of a design different from that which we had with us. Our small drill and staging were built to be used on a sandy islet above the level of high water, and were not suitable for this shoal.

† It must not be thought that we had come entirely unprepared for boring through silt. The results of the former boring expedition had shown only too plainly that heavy silt was to be expected, especially

5 feet 4 inches, above high water spring tide; 7 feet (about) sand, largely foraminiferal; 2 feet pebbly sand passing downwards into shingle; 16 feet very cavernous *Heliopora cærulea* reef-rock with the spaces between the branches partly filled with a growth of *Lithothamnion* and *Polytrema*, and loose running sand. We subsequently dismantled this small drill and converted the staging into a raft, to the corners of which we lashed empty iron tanks in order to increase its buoyancy. Our intention was to put a bore down by means of this raft in the deepest part of the lagoon. On August 6th, all being in readiness, we towed the boring raft out into the lagoon, using the derrick as a mast to which we attached a tarpaulin for sail. Unfortunately for us, before we had reached the centre of the lagoon, a gale sprang up from the S.S.E. The short waves broke heavily and in quick succession over our raft and the 3-inch ropes lashing our tanks became rapidly frayed through. The wind and current were so strong that we were unable to make the shoal of Te Akau Tuluaga, and were drifted rapidly past it towards the north-west passage of the reef, thus running some danger of being blown out to sea. As we were preparing to let go our improvised anchors one of the tanks broke adrift, but was rapidly relashed by the late native magistrate, Opetaia, and his men. As soon, however, as the anchors held, the raft was swept so strongly by the seas that it was almost impossible for anything to live on its deck. Under these circumstances it seemed that the best thing was to try and save the tanks, which were constantly breaking adrift through the snapping of the frayed ropes, leave the raft at anchor, and return when the weather had moderated. The heavy seas had sprung the wooden lids of the tanks, and as they were mostly nearly full of water we let three of them down to the bottom of the lagoon in about 12 fathoms, securing them by ropes to the raft. Meanwhile just as the last tank was made fast the raft heeled over, and eventually floated bottom uppermost. After a tough pull we safely weathered the north-west passage, and returned to camp, in a somewhat exhausted condition, before midnight.

The gale continued for two days longer, and then as the weather slightly moderated we attempted further salvage operations, hoping to get the raft righted and start the lagoon boring. Mr. W. G. WOOLNOUGH rendered splendid service at this part of the work in diving under the raft with the natives and seeing to the unscrewing of the bolts of the submerged iron winch. The recovery of this and of the pulleys, the latter in about 15 feet of water, was a good piece of work in view of the choppy state of the sea. As, however, the raft had dragged its anchors during the gale, the ropes fastening the tanks were found to be broken, and as its buoyancy was insufficient for

in any bore located near the ocean face of the reef, and accordingly we had taken two powerful jetting under-reamers (provided by Mr. W. H. J. SLEE) with the main diamond drill. One of these would have just fitted our bore-hole, but we thought the risk of using it in view of its being absolutely indispensable to the success of the main diamond-drill bore was too great. At the same time it must be said that we were not prepared to find the silting as heavy as it proved to be, at such a distance from the ocean face of the reef as that at which we started our small bore, viz., 360 yards.

boring purposes, in the absence of the tanks, we decided to abandon it, so we hauled in the ropes and anchors, and allowed it to drift on to the lee shore of the reef near Tebuka, where it was quickly broken to pieces by the waves.

Although this attempt at boring the bottom of the lagoon failed, it paved the way for the expedition later under Mr. G. H. HALLIGAN, in H.M.S. "Porpoise," Captain F. C. D. STURDEE, R.N. The very successful boring of the floor of the lagoon by Captain STURDEE and Mr. HALLIGAN in 1898 is described in another part of this volume. For the rest of our stay at the atoll, Messrs. SWEET, POOLE, WOOLNOUGH and I employed our time chiefly in dredging and chopping the reef-rock (between levels of 20 fathoms and 200 fathoms) on the ocean slope of the reef, and in making a geological survey of the atoll. The latter part of this work was accomplished chiefly by Mr. G. SWEET after I left the atoll. Our dredging and geological work is detailed in separate reports in this volume.

We may now return to consider the progress made at the main bore. By July 5th the diamond drill was down 58 feet. On July 10th, when a depth of 62 feet had been attained, a serious accident happened to the diamond drill. The large under-reamer was being used at the time. The lower part, through friction in the silt, became twisted and torn completely off the upper part, and under-reaming being continued for a short time after the accident had happened before it was noticed that anything was wrong, the broken piece became jammed obliquely across the bore-hole. All attempts at recovering the broken half failed for some time. A die was then prepared and its under surface was armed with a mixture of beeswax, resin, and tallow. A pipe was fixed in the centre of this apparatus so as to wash away the silt, while the die was being lowered in the bore-hole. A cast having been obtained by this means of the exact shape of the part of the broken fragment which lay uppermost, one of the tapering screw taps was specially modified so as to fit into the broken under-reamer and great efforts were made to recover it, but all to no purpose.*

The foreman-in-charge told me that it was useless to try fishing any more for the broken under-reamer, and that the only thing to be done was to shift the drill to a

* This accident was due to a defective design in the under-reamer. Instead of jetting water from the very bottom, it was so constructed that the water was jetted from the openings through which the under-reaming "dogs" were swung out. These openings were about a foot above the lower end of the under-reamer, consequently as it was generally necessary to force the under-reamer down, in the process of under-reaming through silt (which kept flowing into the bore-hole at the bottom and sides of the bore) while the upper part of the under-reamer would be working freely—the silt having been washed away from around it by the hydraulic water-jets escaping from the slots in which the "dogs" were hinged—the lower part would be grinding heavily in the silt. At last the torsion became so great that the lower half was twisted off from the upper, causing the serious delay mentioned above. Mr. GARLAND, the mechanic of our party, much improved the remaining under-reamer, after the above accident, by fixing a strong iron pipe right through it, so that the water was jetted entirely from below the under-reamer, instead of from the "dog" slots.

The absolute necessity for having all tools to be used in boring or intended to reach the bottom of the

fresh site. He himself at the time was very ill with a dangerously ulcerated leg; two of the other drill men were also suffering from ulcers though less severely. It looked as though our attempts at boring the atoll would prove a failure. It was now over three weeks since we had landed on the island, and we had bored only to a depth of 62 feet. At this juncture, Foreman BURNS came to the rescue and begged to be allowed a little longer trial at recovering the under-reamer. On July 16th, amid great shouting and cheering, the broken under-reamer was brought to the surface, and the work of lining the bore with 5-inch tubes was at once proceeded with. The coral rock proving somewhat soft below this level, it was found possible to "monkey" down these 5-inch pipes to the depth of 118 feet. At this depth the 5-inch pipes lining the bore-hole screwed on to their lower end, telescoped into the steel shoe, and it became necessary to cut away the telescoped portion with a steel cutter.*

Fortunately we had a duplicate set of left-handed screw rods for this work. Otherwise the result of the boring with the steel cutter would have had the effect of unscrewing the steel shoe, which would have proved fatal to further boring. It was of course impossible to drive down the 5-inch casing any deeper, after the bottom tube had telescoped, so that it at once became necessary to reduce the diameter of the bore. This was a misfortune of no little gravity. It meant that we had now come to our last resource, the 4-inch lining pipes. If any accident should happen to them we could go no farther. Great precautions were accordingly taken in preparing for using our last set of lining pipes. The steel shoe was found to have been a trifle over-tempered, and so it was re-tempered very carefully at the forge until by actual experiment it was ascertained exactly what temper suited it best for cutting coral rock without risk of splintering on the one hand or bending on the other. This having been done, the greatest attention was paid to securing an accurate, close fitting and rectangular joint where the lower rim and the soft steel lining pipe rested, when screwed home, upon the shoulder of the hard steel shoe. Our previous accident had taught us the vital importance of attention to these details.

bore so constructed that they jet water from the very bottom was specially emphasised in this case. In the screw tap, by means of which the broken half of the under-reamer was eventually recovered, the escapes for the hydraulic water had been drilled about 4 inches above the bottom of the tap, and yet although the jets were so near the bottom, it was found impossible even with several tons pressure to force the lower part of the tap through the silt so as to admit of the threads at the upper end of the tap gripping the under-reamer. The tap had actually to have the lower 4 inches cut off it, at our portable forge, before it could be driven through the silt. As soon as this was done, so that the water was jetted from the actual bottom of the tap, not the least difficulty was experienced in driving it through the silt, and getting it to enter the cavity at the top of the broken under-reamer.

* This mishap was due to the fact that the bearing surface of the bottom of the pipe against the shoulder of the steel shoe was not accurately at right angles to the axis of the boring pipe, but instead had a very slight inclination inwards. The result of this was that when the heavy monkeying bulged the threads at the screw joint slightly downwards, the lower rim of the pipe commenced to telescope into the collar of the steel shoe.

The outlook now was none too hopeful. It was nearly a month since we landed; we had bored only 118 feet, had had two serious accidents, and were now reduced to our last set of lining pipes; we knew that if anything happened to them like that which had happened to the 5-inch pipes the boring would be a failure. The foreman of the drill, HALL, was becoming seriously ill, and we feared his leg would mortify, while one of the foremen and one of the drill men were also suffering, though less severely, from ulcerated legs.

At this juncture a *deus ex machinâ* arrived on July 18, in person of Dr. CORNEY, in the Government steamer "Clyde" from Fiji. The "Clyde" had come *viâ* Rotuma, and passing close to Sophia Island, the southernmost of the Ellice Group, Captain CALLAGHAN observed signals for help, and standing in found that there was a shipwrecked crew of 13 Norwegian sailors ashore. Their ship had been lost near Malden Island and they had been drifted about 1660 miles to Sophia Island, in their vain endeavour to make the Fiji Group. They had been on Sophia Island for ten months, and had subsisted chiefly on turtles and fish.

Dr. CORNEY brought us our Sydney mails, together with a welcome supply of cash forwarded by Mr. PITMAN from Sydney, and a considerable supply of fruit, and what was most important a good supply of medicine. He prescribed for the sick, and cheered us all up wonderfully. The numerous sympathetic letters received from our friends were also an immense encouragement. It is not too much to say that the coming of Dr. CORNEY was the turning point in our fortunes. The material to be drilled became somewhat softer, so that it was often possible to "monkey" the 4-inch lining pipes down without having recourse to under-reaming, and this proved an immense saving in time, as our experience proved that it took just twice as long to under-ream as to bore. On July 26, the rods of the big drill became jammed in the silt at a depth of 212 feet. The combined force of the diamond-drill hydraulic cylinders and of the 3-ton jacks failed to move them. The foreman suggested forcing water down the 4-inch lining pipes, to try and loosen the silt around the boring rods. Accordingly the drill pump was kept going all night forcing water down the lining pipes, instead of down the boring rods. By this means the silt between the boring rods and the lining pipes was gradually driven downwards and outwards below the lining pipes into the numerous crevices of the coral rock in the unlined (lower) portion of the bore-hole. This device was successful and the rods were safely withdrawn. This accident proved the danger of boring for more than a few feet ahead of the lining pipes. Two dangers, however, now began to threaten the boring. (1) The supply of coal was getting low, and (2) the jarring, caused by the "dogs" of the under-reamer catching projecting pieces of cavernous coral rock at the sides of the bore-hole, shattered the teeth of the bevelled gearing wheels of the drill. To lessen the first of these dangers the natives were commissioned to cut and carry to the drill supplies of Ngie wood, for which we paid at the rate of 10*s.* for 50 small baskets. The broken teeth of the bevelled wheel were laboriously replaced by GARLAND and the other drill men,

by drilling two holes where each tooth had been lost and then screwing into them a pair of false teeth made of pieces cut from wrought-iron bolts.

At last, however, so serious a break occurred in the crown gearing wheel that the artificer considered that it was impossible to repair it without very considerable delay. We were, therefore, much surprised on our return to the drill camp a few hours later to find that the drill was again in full work. The explanation was as follows:—One of the natives named TILI on seeing the artificer commencing to repair the broken wheel exclaimed that he had got one just like that himself, and presently produced a wheel the facsimile of the broken one, with the exception that it was not broken, but only somewhat worn, which he had just dug up from the roots of one of his cocoanut palms. He had placed it there so that the iron might act as a fertiliser (fig. 17).

Fig. 17.—The Fertilising Wheel.

The explanation also of the mystery as to how he came to be possessed of the wheel was easily given. On the occasion of Professor SOLLAS' Expedition in 1896, among the very few articles left behind was a bevel gearing wheel the counterpart of the one we had broken; it belonged in fact to a sister machine to the drill which we were using. This piece of good fortune enabled us to continue the boring without serious delay; as while one gearing wheel was in use, the duplicate was being repaired.

Satisfactory progress was made, but the greatest anxiety was now felt for the coal supply, which was fast diminishing. Every scrap of coal, including a little left at Luamanife by the previous Expedition, was carefully scraped together, and made to go further by burning with it Ngie (*Pemphis acidula*) wood supplied by the natives. The supply of fuel was almost completely exhausted, when fortunately H.M.S. "Royalist," Captain RASON, R.N., arrived at Funafuti and anchored in the lagoon. Captain RASON at once supplied us with provisions and a sum of money, and promised on his

return from the Gilbert Islands to let us have sufficient coal to keep the drill going until the arrival of the s.s. "Archer." This promise he was good enough to redeem, though at considerable inconvenience to himself, a short time later.

The London Missionary Society's steam yacht "John Williams" arrived at Funafuti on September 5th, when the boring had attained a depth of 557 feet. Mr. G. SWEET, in accordance with our previous agreement, now undertook the charge of the work, it being necessary for me to return at once to resume my University duties at Sydney. Captain E. C. HORE, of the "John Williams," expeditiously embarked such portions of the drilling plant as were no longer required, and early on September 7th the "John Williams" sailed with Messrs. POOLE, WOOLNOUGH and my wife and self for Nukulailai. We arrived at Nukulailai on September 8th, and accompanied the Rev. W. E. GOWARD ashore, when Mr. WOOLNOUGH and I made a hurried traverse and geological examination of the main island. The Nukulailai Lagoon is connected with the ocean only by shallow boat-channels, which are insufficient to lower the level of the lagoon at the same rate as the tide falls outside the reef. Consequently the level of the surface of the water of the lagoon is permanently from about 2 to 3 feet above the level of low-water spring-tides.

We ascertained that at Nukulailai, as at Funafuti, *Heliopora cærulea* had been a very important reef former, and found it in large quantities *in situ*, but dead, upon the ocean platform. It attained a level of about 3 feet above low-water spring-tides, so that at Nukulailai as at Funafuti there is evidence of an elevation of the land, or a downward movement of the ocean, to the extent of perhaps at least 3 feet. From Nukulailai we sailed for Apia, where upon arrival we were most hospitably entertained by the Rev. W. E. and Mrs. GOWARD, my wife at the time being very ill through a severe attack of pleurisy contracted at Funafuti. From Apia, we proceeded to Leone Bay, Tutuila, and thence to Niue (Savage Island).*

Niue has all the appearance of being a raised atoll. We were able to examine part of the coast near the Rev. F. E. LAWES' Mission Station. The island here is distinctly terraced. There are at least three, possibly four, terraces. The topmost is about 200 feet above sea-level, and is distinctly an old coral reef, though the corals have suffered so much from weathering and corrosion as to be difficult of recognition. If we stand on the edge of this terrace it presents the appearance of a slightly raised rim overlooking the plain forming the interior of the island. This plain has all the appearance of having at one time formed the floor of the lagoon of an atoll. This top terrace descends with a steep slope to about 130 feet above sea-level, then there is a more gradual slope to about 80 or 90 feet above sea-level, when a very well-marked second terrace occurs. An examination of this showed that it obviously was considerably newer than the top terrace. Like the latter, it evidently represented an old coral reef, as large reef-forming corals were here very

* 'Bull. Mus. Comp. Zool., Harvard Univ.,' vol. 33 (1899), p. 79.

numerous. We were guided by the Rev. F. E. LAWES to a deep ravine, known as Vailoa, about a mile northwards from the Mission Station. There is a good section here, which showed that the upper part of the old reef was coralliferous only for a thickness of about 20 feet, and that this crust of reef coral rested upon 50 to 60 feet of fine-grained hard limestone, showing thin current beds dipping very steeply. At a yet lower level—about 20 feet above sea-level—was a trace of a third terrace with still more recent coral. At low water there, a reef flat about 100 yards wide is exposed at the base of the limestone cliff, and here living coral and *Lithothamnion* are fairly abundant. Niue appeared to us a raised atoll which would richly repay further investigation. We were informed by Mr. LAWES that the sea cliffs of the island abounded in large caverns, and these should afford good sections. A small collection obtained by us at Vailoa has already been handed over for description to Professor JUDD.

From Niue we were delayed by adverse winds to such an extent that we had to put in to Suva in Fiji on account of being short of coal, H.M.S. "Royalist" arriving there on the same day. Unfortunately both the "Royalist" and the "John Williams" just missed the s.s. "Archer" at Suva, and so we were left in ignorance as to whether or not that steamer would be able to call at Funafuti on her return voyage, to convey Mr. SWEET and the drill party back to Sydney. This missing of the s.s. "Archer" led later to considerable trouble and expense. After being hospitably entertained at Suva by Dr. and Mrs. CORNEY, we re-embarked in the "John Williams," and later fell in with the tail of a cyclone which so seriously delayed us that we did not reach Sydney until October 14th. My first care was to send coal and provisions, and some sort of ship to bring home Mr. SWEET and his party. On inquiry of the owners of the "Archer," as to whether she would call at Funafuti on her return from the Gilbert and Marshall Islands and convey Mr. SWEET and his party back to Sydney, they assured me that the instructions given the supercargo precluded their doing so and they held that he would abide by his instructions.

The New South Wales Government Steamer "Thetys," for which I next made application, proved to have too small a coal-carrying capacity. At the instance of the then Premier, the Hon. G. H. REID, Viscount HAMPDEN, the Governor of New South Wales, wrote to the Governor of Fiji, Sir GEORGE O'BRIEN, urging that the Fiji Government Steamer "Clyde" might be sent to re-provision and re-coal the party at Funafuti. In the event of the "Clyde" not being available, the Government of New South Wales generously undertook to pay for a small ship to go from Fiji to Funafuti and back. As it proved impossible to detail the "Clyde" for the work, the Hon. Dr. B. G. CORNEY, after a good deal of difficulty in view of that time of the year being the hurricane season, succeeded in chartering the "Eastward Ho," a schooner of 45 tons burden, to go to Funafuti. The Hon. A. DUNCAN, agent for the Union Steamship Company of New Zealand, kindly arranged at once to ship by her 10 tons of coal for Mr. SWEET, and this together with provisions for the Funafuti

party, a parcel of diamonds, and some small pieces of machinery for the diamond drill, were at once put on board, and the "Eastward Ho," Captain JONES, sailed from Suva for Funafuti on November 21st. He encountered adverse winds most of his way down, in consequence of which he did not arrive at Funafuti until December 4th, just four days after Mr. SWEET and party had left.*

As events turned out the despatch of the "Eastward Ho" proved to be needless. At the same time in view of the direct assurance of the owners of the "Archer" that their steamer would not call for the expedition, of the probable shortage of coal and provisions at Funafuti, and the urgent need for Mr. SWEET to return to Melbourne before the end of the year, the despatch of the schooner was necessary. She might have been the means, had the "Archer" not called, of relieving the expedition from great embarrassment, and the utmost credit is due to Dr. CORNEY for his prompt and generous action in chartering and despatching the vessel, and particularly to the Government of New South Wales for the help they gave in this matter.

After my departure from Funafuti, Mr. GEORGE SWEET acted as leader of the expedition. The coal supplied him by Captain RASON enabled him to continue the boring until the arrival of the "Archer" on September 21st. Further supplies of provisions and coal were obtained, and the boring was continued to a depth of 663½ feet. A crack then formed in the lower tube of the large boiler which the foreman-in-charge considered dangerous. Mr. SWEET, however, induced the diamond-drill party to fit up the small new boiler, and by this means the boring was eventually carried to a depth of 698 feet. Great difficulty, however, was experienced in carrying the bore to this depth in the last 20 feet, as the small boiler did not afford sufficient steam-power to keep the large pump working at the same time that it drove the drill; hence the rods became at last silted up in the bore and were withdrawn only with great difficulty by means of a powerful monkey. No further boring was attempted this year, and according to his directions, Mr. SWEET had the 4-inch lining pipes pulled up from the bore-hole. An attempt was made also to pull up the 5-inch lining pipes, but they had become so firmly rusted into the bore-hole that when pressure was put on with the hydraulic jacks the top 10-foot length of pipe was torn away from the remainder, thus leaving the bore lined between the levels of 10 feet and 115 feet with 5-inch pipe. This was a fortunate accident as it immensely facilitated the work of re-opening the bore on the following year. Mr. SWEET left a large portion of the drill plant at the atoll as well as 23 tons of coal, and having built a cairn over the site of the drill bore, he embarked with the diamond-drill party on the s.s. "Archer," and arrived in Sydney before the end of the year.

Up to this point, therefore, the work accomplished by the expedition may be summarised as follows:—

* It transpired afterwards that Mr. SWEET had succeeded in inducing the supercargo of the "Archer" to depart from his instructions so far as to call at Funafuti on his return, and take off the whole party, which was done on November 30th.

1st. The depth for which DARWIN had asked that a coral atoll should be bored with a view to testing his theory (500–600 feet) had been exceeded by reaching 698 feet, and a core had been obtained as good as could be expected considering the friable and fragmental character of much of the rock. This was carefully labelled and forwarded early in 1898 to the Royal College of Science, London, for slicing and for chemical and microscopic examination. This core proved that the atoll was formed, from the surface to the bottom of the bore, of calcareous rock chiefly composed of foraminifera, *Lithothamnion*, and *Halimeda*, as well as of reef-forming corals. The lower part of the core appeared particularly interesting and important. At first sight it seemed like a consolidated chalky ooze, and our first impression was that it represented the beginning of the original foundation of the coral atoll. Later examination in the laboratories at the Royal College of Science, London (for the results of which see Sections XII. and XIV.), and at Sydney University, showed that this rock was largely coral-reef material converted into dolomite. It was evident then, that the base of the coral-reef rock had not yet been attained.

2nd. Geological surveys had been made of the various islets of the atoll, in sufficient detail to admit of maps being constructed from them, which it was hoped would be of use later in the study of any changes which the islets might subsequently undergo, as well as in supplying information as to the latest geological history of the atoll. These maps are published with the present volume (Plates 1–19).

3rd. A collection had been made of the various organisms living on the seaward slope of the atoll, from depths of between 20 fathoms and 200 fathoms. These, together with a few samples of the floor of the lagoon, secured by means of a sand-pump, had also been forwarded to the Royal College of Science, London. It was hoped that this collection might prove of use for comparison with the dead organisms in the cores from the diamond-drill bores.

In view of the fact that much of the drill machinery had been left at the atoll as well as a supply of coal, and that it was expected that there would be no difficulty in washing out the silt from the old bore, it was considered very desirable that an attempt should be made to deepen the main bore, and accordingly the Government of New South Wales and the Royal Society of London were approached on this subject. They both generously responded, the former again placing a diamond drill at the disposal of the scientific party and agreeing to bear a portion of the cost of the boring, while the latter contributed handsomely in funds. Mr. A. E. FINCKH volunteered to go as leader of this, the Third Expedition to Funafuti, and the difficulty of transport to the atoll was again got over through the kindness of the London Missionary Society in undertaking to convey gratuitously the diamond-drill party and gear, as well as a further supply of coal, from Samoa to Funafuti.

Meanwhile information was sent to Sydney by Captain CREAK, R.N., F.R.S.,* that

* See Section III, page 36.

the magnetic survey of the atoll made by Captain A. MOSTYN FIELD, R.N., indicated the probable presence of magnetic rock at no great depth, in an area of the lagoon about 2 miles west of the obelisk in the main village. It was therefore decided to attempt to put a bore down near this spot in the bed of the lagoon. As far as we are aware no work of this kind has ever been attempted before. Fortunately, however, the Works Department of New South Wales had for some time previously been perfecting appliances for boring rapidly under a considerable depth of water by means of a water-jet forced through the boring pipes under considerable pressure. The Expedition was fortunate, through the kind consent of the Hon. J. H. YOUNG, Minister for Works, and the Engineer-in-chief, Mr. CECIL DARLEY, in securing for this important work the services of Mr. G. H. HALLIGAN, F.G.S., the Hydrographer to the New South Wales Government, who for many years previously had superintended bores put down by the above method in the harbours all along the coast of New South Wales.

The Admiralty authorised Admiral PEARSON to detail for the work one of the ships of the squadron under his command. H.M.S. "Porpoise," Captain F. C. D. STURDEE, was selected, and the boring gear was at once forwarded to Suva to be picked up there later by that vessel.* In the case of the diamond-drill expedition under Mr. A. E. FINCKH, the drill was placed in charge of Foreman SYMONS, and during the later part of the boring was in charge of Foreman BURNS; the other two members being F. DENT and W. DENT. Mr. W. H. J. SLEE, F.G.S., the Superintendent of Diamond Drills, on the occasion of this Expedition, as on that of the two others, worked with us throughout most actively and cordially, and profiting by the experience gained in the previous borings, was able to send a boring plant which in some respects was even more efficient than the one supplied for the expedition of the previous year. One notable improvement was in the construction of the under-reamers, which are now each provided with four "dogs" instead of two, thus securing for them a steadier rotary movement when under-reaming. It is not too much to say that a large share of the success of this as of the preceding expedition was due to the personal pride which Mr. SLEE took in introducing any improvements into the boring machinery, so that the work done might be a credit to the Government, as indeed it proved to be. Much praise is also due to the officer in charge of the drill stores, Mr. J. S. LEIGH, who spared no pains in the preparation of the drilling plant.

The Expedition under Mr. FINCKH left Sydney in the s.s. "Ovalau" on June 1st, 1898, reaching Apia *viâ* Suva before the middle of the month. H.B.M. Consul E. G. B. MAXE rendered it useful service in arranging for the transhipment of the

* On the occasion of this expedition a supply of coal amounting in all to over 30 tons was presented to us by the Newcastle Collieries Wallsend, Co-operative, Lambton and Burwood. Through Mr. A. GEE, manager of the Sydney Meat-Preserving Company, we received a present of four cases of tinned meats, and through Mr. G. M. MERIVALE, of GIBBS, BRIGHT and Co., who in many other ways assisted our expedition, we were presented with four bags of sugar.

gear from the "Ovalau" at Apia pending the arrival of the L.M.S. steam yacht "John Williams." The "John Williams," Captain E. C. HORE, left Apia on June 16th and arrived at Funafuti on June 20th. The no light task of landing 25 tons of gear, chiefly machinery, and 40 tons of coal on the shore of the lagoon was successfully accomplished by Captain HORE, and preparations were at once made for erecting the drill and stowing the stores and coal, and there was little delay before the boring was commenced, though the natives were rather grasping and lazy.

The old bore-hole was re-opened, and as was anticipated, little difficulty was experienced in washing away the silt to nearly the total depth formerly attained. But some trouble was experienced in the last 50 feet, and the bottom of the old bore was not reached till July 25th. During the first ten days the average rate of advance was slightly more than as many feet; 803 feet being reached on August 4th. The 4-inch lining tubes were carried to a total depth of 727 feet, after which the rock was sufficiently solid to make lining unnecessary. It was, however, so cavernous as to have a very destructive effect on the diamonds (white Cape boarts), and that made progress slow after a depth of 803 feet. Efforts were made to compensate for this by working (with two natives) two shifts at the drills. On September 7th, a depth of 973 feet had been reached, and the core was sent to Sydney by the "Porpoise" with Foreman SYMONS in charge, command at the drill being taken by Foreman BURNS. The supply of diamonds was now running very low and notwithstanding the greatest care it was exhausted on October 11th, when a depth of 1114 feet had been reached. Work then necessarily ceased and the forward lining tubes except the uppermost 111 feet 5 inches were hauled up, and a cairn built over the bore-hole. The time intervening between the conclusion of the bore and the date of departure of this Third Expedition from Funafuti was occupied by Mr. FINCKH chiefly in continuing his experiments on the rates of growth of various reef-forming organisms, especially the corals, the *Lithothamnion* and the *Halimeda*. He also joined with Mr. HALLIGAN in the work of obtaining samples of the submarine slope of the reef on the ocean side, by means of heavy steel chisels and hemp tangles, and in fixing permanent marks on the reef platform facing the ocean opposite the main diamond-drill camp. (See Plate 19.) This work and the results of the biological investigations of Mr. FINCKH, are given in detail in Sections VI and VII. Mr. HALLIGAN's boring of the bed of the Funafuti Lagoon, which proved so successful, is described in Section VIII.

It should be mentioned that the Hon. B. G. CORNEY once more befriended us during this expedition. He took charge of all Mr. HALLIGAN's boring apparatus, arranged for its exemption from customs duties, and stored it at Suva, pending the arrival of H.M.S. "Porpoise." While the success of the technical part of the boring was due to Mr. HALLIGAN, the boring was only rendered possible by the skill with which Captain F. C. D. STURDEE, R.N., moored his ship. This was done with six shackles on each bower, and with the sheet anchor with a shackle and a 4-inch wire

hawser laid about 90 yards astern. During the boring she did not surge more than about 1 foot.* Mr. HALLIGAN and party and the boring plant were conveyed in H.M.S. "Porpoise" from Funafuti to Apia, whence they returned in R.M.S. "Aorangi" to Sydney.

The whole of the material obtained from Mr. HALLIGAN's bores in the lagoon at Funafuti (which respectively reached a depth of 245 feet below sea-level and 144 feet below the floor of the lagoon, and 214 feet below sea-level and 113 feet below the floor of the lagoon) was forwarded to Professor JUDD at the Royal College of Science, London, as was the remainder of the Funafuti core together with Mr. FINCKH's zoological collections and the dredgings obtained by Mr. HALLIGAN and himself from outside the Funafuti Atoll.†

On his return journey to Sydney in the "John Williams," Mr. FINCKH visited some of the Gilbert Islands and found them to be wholly composed, at the surface at all events, of *Lithothamnion.* He arrived in Sydney with the diamond-drill party on January 18th, 1899, bringing with him the portion of the core from 987 feet to 1114 feet. During the time that Mr. FINCKH had been in charge, the Expedition had carried the main diamond-drill bore from a depth of 698 feet to the total depth attained (1114 feet). This included the work of cleaning out and re-lining the old bore-hole. The performance, therefore, in view of the difficulty of boring the cavernous coral-rock, may be considered very creditable to the Diamond-drill Branch of the New South Wales Government Department of Mines.

For the last 387 feet of the boring it was found that the rock forming the sides of the bore-hole was sufficiently strong and free from silt to render unnecessary the further lining of the bore with iron pipes. The 4-inch lining pipes were not carried below the level of 727 feet. This fact is very encouraging in relation to the possibility of deepening this bore at some future occasion. The whole of the 4-inch lining pipes were pulled up at the completion of the boring, but the 5-inch pipes still line the upper 118 feet of the bore, commencing at about 10 feet below the surface.

After the return of the last Funafuti Expeditions we proceeded with the preparation of our geological maps and sections of the islets, while Mr. FINCKH prepared his report on his biological observations, and Mr. HALLIGAN his report on the lagoon borings and fixing of permanent marks on the reef platform. Messrs. HALLIGAN and FINCKH collaborated with me in preparing a report on the dredging. The chief part of the geological work done by us at the atoll was accomplished by my colleague, Mr. G. SWEET, to whom I gladly express my deep obligation

* The success of this boring by means of the hydraulic drill suggests the possibility of boring by some similar method the bed of the ocean even at a considerable depth. Special mention should be made of the services rendered to Mr. HALLIGAN by Mr. ALBERT E. TOMKINS, Chief Engineer of H.M.S. "Porpoise."

† See for the results, Section VII.

for the pains which he has taken to make the maps and sections* as accurate, geologically, as possible, and to the patience with which he has brought together and co-ordinated the results of his numerous observations. We both desire to express our gratitude for the invaluable services in the preparation of these maps and sections rendered by our colleague, Mr. G. H. HALLIGAN, as well as to Mrs. HALLIGAN for the kind help she gave in the choice of colours for them. We are also much indebted to Mr. H. E. C. ROBINSON, our draftsman, whose scientific appreciation of the work and hearty sympathy with it made him at once an enthusiastic worker and useful critic. The unfortunate loss, through theft from a railway carriage in France, of some of our geological maps and sections, might have proved serious had it not been for the fact that we had kept copies of them all. After the maps and sections were finished and on the eve of their transmission to England they narrowly escaped destruction, being about the only material saved from the fire which consumed the premises of the Sydney Publishers, Messrs. McCARRON and STEWART. It may be added that the Expedition made to Fiji in 1901 by Mr. W. G. WOOLNOUGH, B.Sc., F.G.S., which was undertaken chiefly at the suggestion of Professor JUDD, was related to the Funafuti Expedition.

Before closing this narrative I wish to convey my sincere thanks to all my colleagues and friends here and in the old country for their constant help and sympathy, which has encouraged us to persevere when beset, as we sometimes were, with serious difficulty. First of all, I thank my colleague, Professor ANDERSON STUART, for the kind manner in which he has worked with me in organising the Expeditions of 1897 and 1898. Professor SOLLAS and Professor JUDD inspired us with enthusiasm for the work, and the generous contributions of Miss EADITH WALKER and the Hon. RALPH ABERCROMBY, supplemented by funds of the Royal Society, London, and above all the liberal help of the Government of New South Wales in the loan of the diamond drill, made the expeditions possible. To those members of it already mentioned, together with the Hon. T. M. SLATTERY and J. L. FEGAN, with Messrs. D. A. MACALISTER and H. WOOD, to Sir W. LYNE and all other helpers named in these pages, we are deeply grateful.

The handsome services rendered by the London Missionary Society in carrying our gear to and from Funafuti freight-free, and landing and shipping the gear at and from the shores of the lagoon, have already been acknowledged. Captain E. C. HORE assisted us admirably in this work. Only those who have experienced it know the difficulty of landing or shipping heavy packages and machinery on a coral reef, where everything has to be taken in small boats over a shore line beset with coral heads. Mr. THOMAS PRATT, the Sydney Secretary of the London Missionary Society, also rendered us much important help.

The Admiralty made the boring of the Funafuti Lagoon by Mr. G. H. HALLIGAN

* Plates 1 to 19.

possible by detailing H.M.S. "Porpoise," Captain F. C. D. STURDEE, R.N., for this work. To the Senate of the University of Sydney I owe the kind permission that was given me to go as leader of the 1897 Funafuti Expedition, and to my old friend and colleague, Mr. E. F. PITTMAN, A.R.S.M., I am specially indebted for his kindness in delivering gratuitously my geological lectures in my absence. To the Council of the Royal Geographical Society of Australasia, Sydney, and to the President, the Hon. P. G. KING, and the Hon. Treasurer, Mr. H. S. W. CRUMMER, I owe much for assistance during the beginning of the 1897 Expedition, and the latter has been throughout a most unselfish and devoted worker for us.

To Mr. THOMAS WHITELEGGE, of the Australian Museum, I am specially indebted for determining Mr. FINCKH'S Corals, and to Messrs. C. HEDLEY and R. ETHERIDGE, Junr., for much advice and friendly criticism, and to Mr. W. S. DUN, Palæontologist to the Geological Survey, for references to literature. Mr. J. H. MAIDEN, F.C.S., &c., Director of the Botanic Gardens, Sydney, has most kindly worked out the botanical collections from Funafuti. Our hearty thanks are due to the Hon. B. G. CORNEY, M.D., and to the Government of Fiji, for much kind assistance and many concessions.

For the success of the Diamond Drill Boring of 1897 and 1898 I should like once more to state that we were indebted to the steady perseverance and forethought of the Government Superintendent of Diamond Drills, my friend Mr. W. H. J. SLEE, F.G.S., who has worked throughout in the interests of the Expedition with hearty good will and unselfish loyalty. Of all the men who went with the drill party we undoubtedly owe most to Foreman G. BURNS, whose inflexible determination and resourceful energy probably saved the 1897 Expedition from failure at a critical juncture. The excellent services rendered by Mr. HALLIGAN and Mr. FINCKH speak for themselves, it would be hard indeed to over-estimate their value. The unstinted work, too, of my old students, Mr. W. G. WOOLNOUGH and Mr. WILLIAM POOLE, was such as will not readily be forgotten. The Deputy Commissioner for the Western Pacific, Mr. R. TELFER CAMPBELL, rendered us good service in seeing to the safe storage at Funafuti of our gear and coal. The services rendered us by Captain E. G. RASON, R.N., now Commissioner for the New Hebrides, when in command of H.M.S. "Royalist," in supplying us in the hour of need with coal, food, and money are deserving of grateful recognition. I am grateful also to Professor BONNEY and Dr. G. J. HINDE for much kind help, as well as to Mr. F. CHAPMAN and Miss ETHEL BARTON (Mrs. GEPP). I should like also to say how much the 1897 Expedition owed to my wife's presence.*

The work of boring the Funafuti Atoll has proved more difficult, tedious and costly than was at first anticipated. It may appear to some that the results attained are not commensurate with the sacrifices made, and such a view seems not unreasonable at first sight, but it must be remembered that in this, as in many other pieces of

* Mrs. DAVID has written an interesting account of their life on the island, its scenery and the inhabitants—'Funafuti, or Three Months on a Coral Island' (J. Murray, 1899).—T. G. B.

scientific work, the bread that is cast upon the waters may be found only after many days. We have at all events succeeded in carrying out the wish of DARWIN for a core from a depth of 500 to 600 feet in a coral atoll in the Pacific Ocean. We trust that the results of the study of the ample material from our 1114 feet bore, which is now completed by our co-workers in the Northern Hemisphere, and appears in the later part of the present volume, may enable zoologists and geologists to lay more surely the foundations of our knowledge of the origin and growth of coral atolls, and so make our work of some use to science.

SECTION V.

THE GEOLOGY OF FUNAFUTI.

By Professor T. W. EDGEWORTH DAVID, *B.A.*, *F.R.S.*, *and* G. SWEET, *F.G.S.*

[See PLATES 1–19.]

As regards scale, the maps have been reduced to, as nearly as possible, 400 feet (121·95 metres) to the inch. An actual scale in feet and metres is reproduced on each map, so that if any slight error exists in the reduction of them by photo-lithography or through subsequent shrinkage, such error corrects itself through the scale having participated in the deviation of the map from the uniform standard.

As regards the scope of the work, the geological boundaries have been drawn only down to the level of low-water spring tides; no attempt, for example, has been made to show the boundaries of the great submarine sheet of *Halimeda* sand which forms the floor of all the deeper portions of the lagoon.

Reference to the index sheet Plate 1 will show that we have omitted from the map some portions of the atoll rim which are distant from any islets, as, for example, the portion north of the islet of Fuagea and intervening between it and Fuafatu, and the long stretch of reef between Pava and Mulitefala. The total proportion of the atoll rim thus omitted from the geological maps is about one-fifth of the whole circumference.

As regards the method of mapping, we took as our basis for the general outline and orientation of the islets the British Admiralty Chart, No. 2983, compiled from surveys by Captain A. MOSTYN FIELD, R.N. The details shown on the geological maps were filled in from our own traverses, made chiefly by pacing (in some cases by chaining) and measuring angles with a prismatic compass, the traverses in most cases being checked at least once. The portion of the reef shown on Plate 17 was, however, measured with a tape by Mr. A. E. FINCKH, while the positions of the permanent marks opposite the main diamond-drill bore, on the main island, both on the ocean and lagoon sides (see Plate 19), were chained by Mr. G. H. HALLIGAN, as also were the distances between Professor SOLLAS's Nos. 1 and 2 diamond-drill bores and the main diamond-drill bore. In the case of the section shown on Plate 17 the levels were taken by Mr. G. H. HALLIGAN, with a 12-inch dumpy-level. In other cases, however, the levels upon which the numerous geological sections are based were made by sighting from the object whose level was to be determined to the horizon line of the ocean, noting where this line intersected the levelling staff held at

the position of high water. The height of this point of intersection above the zero of the level was taken as the height of the object above high water, and as the eye of the observer was seldom more than a few yards distant from the levelling staff, the results were approximately accurate, and the method was certainly expeditious. In some cases the levels were taken by means of the spirit levels of our clinometers. Where special importance attached to the levels, as in the case of the raised *Heliopora cærulea* reefs in the mangrove swamps of the main island (see Section 9 of Plate 9) the levels were checked several times and may be considered to be fairly correct. As the details of the geological survey were filled in mostly by pacing, errors of several yards no doubt occur in places. The general shape of the islands, however, is fairly accurate as shown, or at all events sufficiently so to form a record for future reference.

As regards the method of showing the outer boundary line of the rock marked O.L.10, on Plate 17, the living *Lithothamnion* zone, the following plan was adopted. Mr. A. E. FINCKH having accurately measured, with a tape, the details of the reef platform down to low-water springs, opposite the main diamond-drill camp, this plate was drawn from his traverses, and the outline shown on it was then repeated over and over again to represent the characteristic outline of the outer shore of the reef at low tide, but conspicuous indents in the shore line are shown in their true position by indentations of the boundary line between O.L.10 and O.3 as, for example, near S^2 to the right of section-line 9 on Plate 9. In the same way the pattern for the boundary of the reef lagoon-wards at low tide has been taken from Mr. FINCKH's traverse of the lagoon platform of the reef to the north of the Mission Church (see Plate 17).

The general shape and submarine contour of the atoll may be seen from the two figures on Plate B. These have been made from a plaster model in the Australian Museum, reproduced from a wooden model carved by Captain E. C. HORE, of the London Missionary Society's steam yacht "John Williams." Captain HORE carved his wooden model to true scale, taking as his basis the British Admiralty Chart, No. 2983. In general outline the atoll resembles a caricature of a human head, facing the west, the positions of the mouth and eyebrow being indicated by two dark streaks marking deep passages into the lagoon from the ocean. The greatest diameter of the atoll lies in a direction N. 20° E. (true). KRÄMER* has argued that this elongation of the islands of the Ellice group, in common with that of numerous other coral islands of the Pacific, is due to the direction taken by the prevalent ocean currents and winds. In the case of Funafuti, however, the prevalent winds from about March to November are the S.E. or E.S.E. trade winds, whereas from December to February north-westerly monsoonal winds prevail. Thus the long axis of Funafuti is almost at right angles to the prevalent winds. As regards its shape in relation to

* "Ueber den Bau der Korallenriffe und die Planktonvertheilung an den Samoanischen Küsten," pp. 88–90.

(1) Model of Atoll, viewed from Above.

(2) Model of Atoll, viewed from Side.

the prevalent ocean currents, it is somewhat doubtful what their direction really is. According to the British Admiralty Chart of Funafuti Atoll, the current during July flows from about E.S.E. to W.N.W., except where it is locally deflected by the atoll. Mr. G. H. HALLIGAN has drawn our attention to the fact that on the "Quarterly Current Charts—Pacific Ocean," published by the Admiralty, October 23th, 1897, there is the following note: "Note A.—The currents among the Ellice, Gilbert, and Marshall groups are very irregular and uncertain, both in strength and direction, more particularly from November to March."

From BERGHAUS'S "Physikalischer Atlas" (II Abt., Hydrographie, Taf. VI) Funafuti appears situated just on the inside of a circular current which sweeps in a north-westerly direction, skirting the N.E. side of the Ellice group, thence trending westerly between the Ellice and Marshall Islands, thence in part turning south towards the Santa Cruz Islands, and finally recurving towards the southern end of the Ellice group. The direction in which pumice has been found to drift across the Pacific to the Ellice group is also in favour of an easterly current, for, as stated elsewhere in this report, pumice, erupted in May, 1878, at Blanche Bay, New Britain, nearly 1500 geographical miles west of Funafuti, literally covered the shores of the Solomon Islands, and thence vast quantities of this material were carried further eastwards to the Ellice group, and we learn that hundreds of tons were thrown up there on every island.*

The trader, Mr. O'BRIEN, at Funafuti informed us that the drift pumice at Funafuti arrived from the west, and this statement is borne out by the fact that at Funafuti Atoll the pumice is more abundant and occurs in larger pebbles on the west side of the atoll than on the east side. Possibly the (so-called) Carolinian Monsoon current may extend further east than is usually supposed, and this might account for the easterly drift of pumice from New Britain to Funafuti.† On the whole, therefore, it appears that whereas a W.N.W. current usually prevails at Funafuti during the trade-wind season, an easterly current may prevail at other seasons of the year.

The elongation of Funafuti in a nearly meridional direction is therefore more likely due to its being situated on a volcanic zone, or fold ridge than to any influence of prevalent winds and ocean currents. This would account for the remarkable elongation of Funafuti towards its southern end, the neck of the head. The submarine relief of the atoll at this point is very suggestive of some rock other than coral forming the nucleus of the foundation. It will be observed that the atoll has a second axis of elongation in an east and west direction, nearly normal to the

* 'Nature,' vol. 19, 1878–9, p. 108.

† Fragments of our raft, which was wrecked on August 6th, 1897, about 4 miles west of the Mission Church, were picked up by us about a week later at Tengako and Funafara, respectively at the N.E. and S.E. extremities of Funafuti Atoll. In view of the fact that no winds other than the S.E. trades had been blowing during the interval, this direction of drift from west to east seems remarkable.

principal axis. A possible explanation of this elongation in an east and west direction is suggested by the results of the Admiralty magnetic survey.

Captain W. E. CREAK's reductions of the magnetic observations by Captain FIELD and the officers of H.M.S. "Penguin" locate an area of great disturbance of the vertical magnetic force at a point bearing from the Mission Church on Funafuti main island S. 87° W., 5004 yards distant, and distant about 1311 yards from the east extremity of Te Akau Fasua. The long axis of this area runs east and west, and at about $5\frac{1}{2}$ miles further west is a second area of magnetic disturbance, of which the long axis trends about N.N.E. and S.S.W. A prolongation westwards of the long axis of the first disturbance area intersects this second disturbance area about midway between its two foci. A mass of magnetic, and probably therefore volcanic rock, may underlie this spot. If so, the following may be a possible explanation of the existence of this submarine promontory.

It may be of volcanic origin. In support of this view we may observe that the atoll is widest at this spot and has a corresponding promontory and shoal at its westernmost point (Fuafatu) which lies due west of the eastern promontory. This suggests a possible cross line of volcanic fissure trending east and west, parallel to the trend of those upon which the numerous small basaltic craters of Rotuma (the nearest volcanic island to Funafuti) have been built up.

With reference to the general configuration of the floor of the lagoon, it will be noticed, on glancing at the Admiralty chart, that the lagoon is most shallow in the most sheltered areas. This is owing to the chief deposition of sediment taking place to leeward of the chief land areas, and at the inner angles of the reef, as, for example, is the case just west of Fongafale on the inner bend of the main island and along the lagoon side of the western rim of the atoll from Fuagea to the "pocket" inclusive. The effect of shelter in favouring sedimentation is well shown by the incurving of the 20-fathom contour line to the west of the islets of Funangonga and Funamanu. In those parts of the lagoon where recent sedimentation has not been heavy enough to efface this feature a well-marked low submarine cliff may be noticed, bounding the reef platform lagoonwards,* and from 1 fathom to about 4 fathoms deep. One would expect to find it the exception rather than the rule that a submarine cliff such as this should be preserved at all under conditions of strong variable currents and heavy silting such as obtain in the Funafuti Lagoon.

As regards the contour of the island in cross-section, the general shape is shown in the lower figure (2) on Plate B, also a photograph of Captain E. C. HORE's model. The highest point of the atoll, situated near the extreme S.W. end of the islet of Telele, is 16 feet above high water, as determined by one of us (Mr. SWEET). The general depth of the lagoon is about 20 fathoms, the two deepest spots measured being 30 fathoms. As mentioned in Section IV this lagoon floor is formed

* Reference to this has already been made by Mr. STANLEY GARDINER. 'Proc. Camb. Phil. Soc.,' vol. 9, p. 423.

and the 3000-fathom line at rather more than double that distance. The soundings taken during the survey by H.M.S. "Penguin" show that there is an absence of any connecting ridge between Funafuti and its nearest neighbours in the Ellice Group, Nukufetau and Nukulailai. Funafuti is thus an isolated conical mountain rising 16,000 to 18,000 feet above the general level of the surrounding ocean floor, and crowned with sand and reef.

The two deepest channels into the lagoon respectively, compared to the mouth and eyebrow of the head, are, we think, of considerable geological antiquity. It may be something more than a coincidence that they converge lagoonwards on the spot where Captain CREAK has located the chief focus of magnetic disturbance. Possibly they may indicate the site of submerged valleys or silted up inlets.

Symbols used on Maps and Sections.

As regards the meaning of the symbols and of the numbers employed an index is given on Plate 2, but it will be as well to add some further explanation of them here. The symbol O. means that the rock so denoted was formed chiefly on the ocean side of the reef, the symbol L. that it was formed chiefly on the lagoon side, and the symbol O.L. that it was formed on both the ocean and lagoon sides of the reef. The higher numbers denote the newer rocks, the lower numbers the older. The rock marked O.L.1. and denoted by the blue colour on the geological maps, is the oldest and by far the most important of those forming the hard rock of the atoll ring. It is the substratum of the principal islets, probably of all the islets, at all events of those on the north, east and south sides of the atoll. It is composed chiefly of *Heliopora cærulea*, with occasional clusters of *Porites*, which usually accompanies it among the reefs of the eastern side. On the western side of the atoll, however, though *Porites* was present, and in the south-western part was much more abundant than on the eastern rim, very little *Heliopora cærulea* was observed, and even that was not *in situ*, but present as fragments in the reef-breccia sheet. On the western side of the atoll, however, *Porites* greatly predominates, no old reef-rock formed of *Heliopora cærulea* being there visible, in spite of the fact that there is an abundance of *Heliopora cærulea* living inside the lagoon on its western side, but it must be noted that no excavations were made deep enough on this rim to reach the general horizon of the *Heliopora.*

The *Heliopora cærulea* occurs in stocks from a few feet up to 24 feet in diameter. These are best seen at the Mangrove Swamp. (See Plate 18.)

As stated on the plate, the shape and size of the coral heads figured are drawn to actual scale from measurement, whereas the branching is merely sketched with only approximate accuracy. An interesting feature in connection with this development of *Heliopora cærulea* is the fact that at the centre of nearly every one of the larger heads a cushion-like mass of *Porites* is found *in situ*, in each of which

concentric and radiating cracks, nearly vertical, were plainly visible. As shown on Section 9 of Plate 9, a raised reef of *Heliopora cærulea* attains in the Mangrove Swamp a level of about 4½ feet above low water, and rises a little above the level of high water in the plantation to the west. The occurrence of this raised reef has already been noticed and described by Professor SOLLAS.* This occurrence indicates a downward movement (see note at end of this section) of the shore line (possibly due to an actual elevation of the land) of from 4½ to over 6¼ feet. It has, however, been suggested that the occurrence *in situ* of coral heads of *Heliopora cærulea* up to the level of high water at Funafuti can be explained otherwise than by such a movement. Messrs. HALLIGAN and FINCKH have pointed out that on the north side of the islet of Amatuku (see Plate 12 for plan and also Section 4 of same Plate), in this atoll, small heads of *Heliopora cærulea* are found living in a tidal pool on the reef platform at a level of between 1 and 2 feet above low water.

At Funamanu Islet also we observed one or two small stocks of *Heliopora cærulea* living a few inches above the level of low water. We also noted the fact that at the atoll of Nukulailai, 52 nautical miles S.E. from Funafuti, the level of the lagoon, even when the tide had fallen, remained several feet above the level of low water. This was due to the channels and tunnels in the reef rim at that atoll being insufficient to lower the level of the lagoon at a rate rapid enough to keep pace with the fall of the tide outside the reef. It has been suggested that formerly similar conditions may have obtained at the Mangrove Swamp at Funafuti, and that the raised *Heliopora cærulea* reef there developed may have grown in a part of the lagoon, the level of which was permanently that of high water, through being completely land-locked. This view, however, does not explain the fact that at its highest point, as at the plantation south of Fongafale, the dead *Heliopora cærulea* appears to extend above the level of high water, while the dead *Lithothamnion*, of the encrusting type, which so largely forms the cementing material of the breccia sheet, certainly extends in numerous places up to quite 2 feet above high water.

It may also be mentioned that numerous *Porites* heads *in situ*, like those at Tutanga, Te Falaoingo and Tefala, and those at Pava in the Funafuti Atoll are in many cases over a foot, some at Te Falaoingo 4 feet above high water. These immense heads could not have grown in land-locked reef pools, but must have flourished under the most favourable conditions, such as free access to food-bringing currents, &c., would provide. Outliers too of the reef breccia, to be described presently, show that coral and *Lithothamnion* occur *in situ* upon them up to levels of over 5 feet, in one case 10 feet above high water. At the islet of Motusanapa one of us (Mr. SWEET) has observed the largest and highest breccia outlier as yet noticed at this atoll. Its summit is 10 feet above the level of high water, and as he considers from its surroundings that it was all originally cemented and consolidated at a level not exceeding that of low tide, this occurrence would indicate a downward

* 'Nature,' vol. 55, 1897, p. 376. See also *supra* p. 20.

movement of the shore line in this part of the atoll to the extent of at least 16 feet. The conclusion, therefore, seems to follow that at Funafuti there has been such a movement of the shore line to the extent of at least 6 feet and almost certainly 16 feet.

The interspaces between the large radiating branches of *Heliopora cœrulea*, at the Mangrove Swamp, are filled with "sand" composed of foraminifera and broken fragments of *Lithothamnion* and of molluscan shells. The tidal water finds an easy passage through the sand between these branches, from the ocean side of the reef to the lagoon platform. As the tide outside the atoll rises, the water wells up from a great number of holes in the lagoon platform. These are from a small fraction of an inch up to about 6 inches in diameter. In fact, the rock of the atoll rim, in its upper portion at all events, seemed as porous as a huge sponge, being honeycombed in all directions with tortuous irregular hollows, generally filled with foraminiferal sand. It was these countless hollows in the reef rock, filled with running sand, which rendered the task of boring the rock so difficult, as the sand was continually being washed in from them so as to choke our bore-hole, wherever its sides were not lined with the steel pipes. One of the largest of these openings is that known as "the blow-hole," near the north extremity of the Mangrove Swamp. (See Plate 9.) This might be more correctly described as a swallow-hole. It is about 4 feet in diameter, and is distant 130 yards from the inner edge of the reef platform at low tide. Nevertheless, the surface of the water in it pulsates in unison with the movements of the waves outside the reef. Plate C, fig. (1) shows the general appearance of this swallow-hole.

As regards colour the *Heliopora cærulea* of the rock type O.L.1 retains its original indigo-blue colour only in cases where it has been protected, as on the reef platform, by some such covering as that afforded by *Lithothamnion* or *Carpenteria*. In long exposed positions it is mostly bleached superficially to a pale grey, passing inwards into a greenish tint.*

On the lagoon platform the dead *Heliopora cœrulea* reef terminates lagoonwards in a low cliff, veneered with *Lithothamnion* as described in Section VI.

At the Taro Plantation, west of the Mangrove Swamp, where the old *Heliopora cœrulea* reef attains its highest level, the presence of 6 per cent. of phosphoric acid in the soil shows that this part of the atoll has perhaps a certain amount of guano deposited upon it.† The fact, however, should be mentioned that the soil there has been enriched in places by material carried there by the natives from other islets in this atoll, and we were informed that a little of the soil had been brought over as ballast from Samoa.

* For the chemical composition of this colouring matter, see MOSELEY, 'Report, Challenger,' vol. 2, pp. 109–110; and LIVERSIDGE, 'Roy. Soc. Proc., N. S. Wales,' vol. 32, 1898, p. 256.

† The following analysis is quoted from 'Memoir III.,' Part I., of the Australian Museum, Sydney, "The Atoll of Funafuti," p. 76 :—

(1) Swallow-hole near the Mangrove Swamp, Funafuti.

(*See p.* 71.)

(2) Negro-heads on Shore, Fatato Islet.

It will be noticed that in the sections of the north, east, and south portions of the atoll the *Heliopora cærulea* reef is shown in all cases to be the foundation rock. As regards its boundary lagoonwards it does not in all cases terminate at the low cliff at the edge of the lagoon platform, but can be traced for some little depth on the bottom of the lagoon below low tide. In the northern portions of the lagoon the dead *Heliopora cærulea* merges in places into the living *Heliopora cærulea*, which in that part of the atoll covers large areas of the floor of the lagoon. As regards the development of the old *Heliopora cærulea* reef on the ocean side, one of us (Mr. G. SWEET) discovered that it extended under the Hurricane Bank in several places below a thin crust of dead *Lithothamnion*, while its extension to considerably beyond the outer edge of the Hurricane Bank was ascertained by blasting the intensely hard surface of the ocean platform with gun-cotton.* It was also found *in situ* in the corrosion zone of the reef platform (O.2.B.), as well as up to the edge of O.L.10 between the channels, as was seen a little to the north of easternmost point of the main island.

The positions of these blasts are shown on Plate 9. In view of the fact that scarcely any trace was found by us of living *Heliopora cærulea* on the ocean side of the reef, it is strange that there should be on this side such an immense development of dead *Heliopora cærulea* reef *in situ* on the ocean side of the reef. A great extent of the same dead reef can also be seen a few fathoms below low water west of the main island. The evidence supplied by Professor SOLLAS'S Nos. 1 and 2 diamond-drill bores and our main bore with the small bore to the west of it, shows that the *Heliopora cærulea* reef extends to a depth of at least 40 feet below high water. *Heliopora cærulea* still retaining traces of its blue colour was also found in the core from the main bore down to depths of at least 100 feet. As regards its horizontal distribution the table of areas of the rock types represented at Funafut

Analysis of air-dried sample of soil from the Taro Plantation. This consists of decomposed *Heliopora cærulea*, with an admixture of foraminiferal shells, chiefly *Tinoporus* and *Orbitolites*.

Hygroscopic moisture	1·81
CaO	47·23
MgO	1·07
K_2O	·05
Na_2O	44
Fe_2O_3	·28
P_2O_5	6·00
SO_3	·44
Cl	·02
CO_2	33·65
Organic matter	8·97
Residue (insol. in HCl)	·04
	100·00

* This was kindly supplied by Captain E. RASON, R.N., of H.M.S. "Royalist.

Atoll shows that the *Heliopora cærulea* reef is very extensively developed, and in view of the fact that a large portion of what is shown on the maps as the dead *Lithothamnion* (O.3) is merely a thin crust overlying the *Heliopora cærulea*, the latter must constitute more than one half of the whole area of the portion of the atoll, shown on the geological maps, and perhaps underlies the whole of it. That *Heliopora cærulea* may underlie that portion of the reef platform seems likely from the fact that there are large areas of it living and extending from Fuafatu northwards to Pava on the lagoon side of the atoll rim, and this view is supported by the discovery of fragments of that coral in the breccia of the western rim, as already stated. The most conspicuous feature about the reef platform on the western rim of the atoll is the immense development *in situ* of dead *Porites*. The bosses of this coral, as described by one of us (Mr. G. SWEET), are from 5 to 8 feet in diameter, and 5 to 6 feet high. They are mostly traversed by radial and concentric cracks.

Although *Porites* is one of the hardiest types of coral at Funafuti, and some species live in pools on the reef platform at a height of over 2 feet above low water, still these are exclusively thin flattened forms, the shape of which has adapted itself to that of the shallow pools, and they are by no means comparable to the immense heads of this coral *in situ* on the reef platform, so strikingly numerous between Fuagea and Avalau. Their occurrence at levels up to 4 feet above high water confirms the view already inferred from other evidences that there has been a recent downward movement of the shore line to an extent of certainly over 6 feet, and almost certainly to 10 feet. This 10 feet is calculated by adding 4 feet (the extreme height of the *Porites* above high water) to 6¼ feet (the range of the tide).

The Breccia.—Next in age, and newer than the *Heliopora cærulea* and *Porites* reefs, is the well-defined breccia horizon denoted O.2.A., O.2.B., O.2.C., O.2.D., and O.2.E., including also patches of very dense sandstone occasionally met with in the breccia. It is formed largely in its lower portions of fragments of the older *Heliopora* and *Porites* reefs cemented partly by *Lithothamnion* and partly by *Polytrema planum*. The former of these two cementing agents has rendered the upper portion of the breccia particularly dense.

The breccia is extremely hard, so that it is a difficult matter, where it is exposed in the smooth surface of the reef platform, to detach chips of it even with a hammer and chisel. It generally extends from about 3 feet below high water up to from 1 to 2 feet above high water. If, however, the outliers observed along many parts of the ocean beach, and especially at Motusanapa, be included as portion of the breccia, then it must be conceded that in places it reaches a height of about 10 feet above high-water level. The thickness thus varies from 4 feet up to about 13 feet. Our general conclusion then is that this breccia has been formed below water, mostly at or below the level of low tide, probably the latter. It is clear that in many of the cases where the breccia surface is from 1 to 2 feet above high water a downward movement of the shore line of 7 to 8 feet is implied.

Unfortunately we did not obtain specimens of the highest points of the breccia at Motusanapa, but we have no reason to suspect that it is in any way different from the breccia which we have examined in thin sections under the microscope from other localities in the atoll.

The breccia sheet has apparently at one time covered the reef proper around perhaps the whole of the rim of the reef platform, though now there are wide stretches of this from which it has been almost completely denuded. Nearly all the islets of the atoll have a foundation of this material, or at least a rampart of it, along their shore line facing the ocean. In some cases there is an outer line of extremely dense breccia marking the most advanced position oceanwards occupied by that material at a time when it formed the foundation for islets which have since been driven inwards over the reef platform towards the shore of the lagoon. Such an outer line is well seen between the islets of Pava and Mulitefala at the north end of the atoll (see Plates 12 and 13, and see Section 1 of Plate 13, which shows how the ancient islet of Fualifeke has been driven lagoonwards from its former position), and also in the south-western and southern part of the atoll from Fuagea past Tutanga and Avalau to Nukusavalivali. (See Plates 3, 4, and 5.) It is to be noted that all the high breccia outliers, or breccia negro-heads, are situated between this line and the present breccia rampart. As regards the subdivisions of the breccia sheet, O.2.A. represents the portions of it exposed in the central parts of the islands, where at low tide it is subjected during the heavy intermittent tropical rains to the corrosive action of humous acid. The surface is very uneven, bristling with sharp points. It is typically developed at the main island and Tutanga.

O.2.B. represents a portion of this breccia sheet forming the third zone inwards from the edge of the reef platform at low tide (see Plate 17 and Section by Mr. G. H. HALLIGAN on line C–D). Most of the space between the outer line above referred to and the breccia rampart belongs to this zone. It is even more jagged and more bristling with sharp points than O.2.A. A zone of this rock is in some cases found on the lagoon platform as well as on the ocean platform. The corrosion is apparently due partly to rain-water, partly to sea-water.

The reason why the jagged points are not broken off by the force of the waves is that this zone is at present out of range of the loose shingle at the base of the Hurricane Bank. In addition to the high outliers already referred to, there are in places within the zone small outliers and "negro-heads," mostly just covered at high tide. The lower figure on Plate C shows some of these "negro-heads" at Fatato Islet, on the lagoon platform of the reef. We agree with Professor AGASSIZ's general opinion that such "negro-heads" are of the nature of outliers, and do not represent once loose blocks of reef limestone cast up upon the reef platform by storms and subsequently cemented down. Our observation at Funafuti led us to the conclusion that these "negro-heads" indicate downward movement of the shore line.*

* It should be stated, however, that Messrs. HALLIGAN and FINCKH consider that these blocks are not *in situ*, and they do not therefore look upon them as evidence of such a movement of the shore line.

Inside the jagged corrosion zone O.2.B. is an intermittent smooth white zone of erosion where the surface of the breccia is being continually pounded and rubbed by shingle rolled over it at high tide by waves breaking against the Hurricane Bank. (See Plate 17.) Next comes the zone O.2.D. (See Plate 17 and Section C–D.) This, as stated on the index, forms a low wall or steep slope extending from 2 or 3 feet below high water up to 2 or 3 feet above. The case at the S.W. end of Telele, where an outlier of this breccia attains a height of over 9 feet above high water, has already been mentioned. This zone forms in place low ramparts with re-entering angles and outlying rugged pinnacles. The general aspect of this part of the breccia is shown in the upper figure of Plate D.

The manner in which delicate laminæ of *Lithothamnion* occur as cementing material in this breccia, up to heights of from 1 to 2 feet above high water, is proof that even this upper part of the breccia was formed originally under water, and the presence *in situ* of the *Lithothamnion* shows that it was formed not much above the level of low tide. The reef breccia marked O.2.E. is other than and in some cases newer than O.2.A., O.2.B., O.2.C. or O.2.D. It is typically developed on the main island just beyond the stretch of sand on the lagoon beach north of the village of Fongafale. It is also developed in places to the south of Fongafale, as near Luamanife and to the south of Fuagea, &c.

We may now pass on to consider the strata mostly, if not wholly, newer than the breccia sheet. L.2.A. is an old conglomerate formed on a former shore of the lagoon, and composed of well-rolled pebbles of coral more or less cemented together. This rock becomes almost a sandstone in places. It is typically developed at the main island about 230 yards easterly from the Mission Church. Thence it trends in a northerly direction close to the path on the line of Section 10 A–B of Plate 9. We think that on the main island it marks an old shore line of the lagoon or possibly a channel in the old *Heliopora cærulea* reef, probably the former. It is about 4 feet in thickness. It is also typically developed at the N.W. end of Amatuku. (See Plate 12, Sections 1 and 4, Amatuku.) The conglomerate is bedded, the strata dipping W. 30° S. at 1 in 15. At its base the conglomerate rests upon a hard foraminiferal *Lithothamnion* sandstone. The lower figure on Plate D shows the general aspect of this old lagoon conglomerate at Amatuku. (The large trees are Fetau trees.)

The top of this conglomerate at Amatuku is fully 6 feet above high water, as shown on the Section. As the conglomerate is fairly firmly cemented, and as no such cementing can now be seen in progress in the atoll above high water, and, indeed, very little above low water, we are of opinion that this evidence, like that afforded by the raised *Heliopora cærulea* reef and the outliers of reef-breccia, implies a downward movement of the shore line of not less than 6 feet in this case, and as there are water-worn pebbles of breccia in the conglomerate, this elevation must have been subsequent to the consolidation of the breccia sheet.

Another interest which attaches to this old lagoon conglomerate is that it forms

(1) Breccia Masses on Shore.

(2) Conglomerate, Anatuku.

on the main island a probable index of the amount of material added to the latter by silting since the deposition of the conglomerate, the latter being perhaps nearly contemporaneous with, though a little newer than, the old breccia sheet. As will be seen by referring to Plate 9, the island has been extended westwards for a distance of about 270 yards since the time this conglomerate was formed. The rock of type L.2.A. passes insensibly into L.3. L.3 is defined on the index as hard foraminiferal *Lithothamnion* sandstone, passing in places into fine conglomerate. It is of various ages and has been formed chiefly on the lagoon side of the reef, but exceptionally it occurs on the ocean side of the reef, as shown on Plate 10, where Section line 3 crosses the island. It is usually bedded, having a thickness of from 3 to 5 feet. It is found now chiefly between the levels of high and low tide. In places, as at the islet of Mulitefala, it extends up to fully the level of high tide. Its general appearance is seen on Plate E (upper figure), the photograph being taken near the N.W. end of the islet of Amatuku. It is formed of more or less water-worn fragments of *Lithothamnion*, *Halimeda* and coral, together with numerous foraminiferal tests, especially those of *Orbitolites* and *Tinoporus*, and fragments of molluscan shells, the whole being bound together by a clear calcareous cement.

It appeared to us that the most important questions about this sandstone are (1) as to its mode of origin, with special reference to the nature of the cement, and (2) as to its age. With regard to the second question it is clear that its age is variable. In certain areas it is indubitably of some antiquity, as, for example, at Mulitefala,* where it is evident, from the direction of dip of the calcareous sandstone (or sandy limestone), that since its formation the whole islet has been driven in lagoonwards, so that this sandstone, originally formed at the back of the island, is now situated in front of it. A similar case occurs at Fualifeke Islet† and at Tefala. On the beach at Fuafatu, on the other hand, a fine coral rubble is even now being cemented into a fine conglomerate. An examination of specimens from the latter in thin sections shows the cement to be a fibrous radial calcite. In the case of the calcareous sandstones, sections examined under the microscope show that they too owe their cement to a secondary fibrous carbonate of lime devoid of organic structure. At first we inclined to the opinion that no cementation of loose material was taking place between the tide marks, but that it had all formed at or below the level of low tide. At the same time a careful examination of this sandstone showed that incoherent layers of sand were frequently interstratified with it and occurred in beds parallel to those of the sandstone.

The extensive corrosion so noticeable towards the centres of the islets shows that carbonate of lime is being removed extensively by the agency of humic acid from these areas. Probably carbonate of lime is being removed at an equally rapid rate from the banks of sand and rubble on either side of these depressed central areas,

* See Plate 12, Section 2, of Mulitefala.

† See Plate 13, Section 1, of Fualifeke.

though the work of corrosion is in those latter cases less apparent, because as fast as the material is dissolved away from beneath it is partially renewed by additions of new material either from the ocean side or from the lagoon side of the reef. In fact the reason for the existence of this central hollow or groove running down the centres of the islets is that while the whole of the reef rim above low tide is being dissolved slowly by humic acid, the work of construction on the portions nearest to the lagoon and ocean are nearly sufficient to keep pace with the destructive solvent forces. In the central portions of the islets, however, the destructive forces have it all their own way down to the level of low tide, as these portions of the islets are too far distant from the Hurricane Bank on the one hand, and the Lagoon Bank on the other, to receive any additions of new material to replace the loss through solution. Obviously the calcium carbonate in solution must go somewhere. Part of it sinks through crevices and irregular hollows in the reef into the sea beneath (the foundations of the islets as already stated being as porous as a sponge), and part oozes outwards into the beach sands. Heated as these are by the tropical sun they promote rapid evaporation in the calcareous solutions passing through them. Hence calcium carbonate would form and be deposited as cement between the sandy particles.*

Mr. STANLEY GARDINER'S observations on the formation of a similar rock at Rotuma have such an important bearing on this subject that we quote them here† :—" On the beach between tide-marks it (our beach sand) ends with a beach sandstone formation. . . . The top of a layer which is the part most exposed to the air and to the waves is the hardest. If it is removed, as is constantly done by the natives for gravestones, it seems to be rebuilt, growing up as it were from the broken edge ; fresh layers on the outside seem to be formed, too, in a similar manner."

It may be added that a somewhat similar calcareous sandstone, of quite recent origin, occurs on the beach between tide marks at Long Reef, near Sydney. Its occurrence just at this spot is in that case clearly due to a local soakage of humous acid from an adjacent peat swamp. The reason for the calcareous sandstone there and at Funafuti, &c., forming just between tide marks, the upper limit being usually a little below the level of high water, is related probably to the limits of the saturation zone (*i.e.*, the zone saturated by soakage from the land), the upper limit of which, of course, varies with the tides, but which is normally a little below the level of high tide

* An analogous deposit is forming at Norfolk Island, as described by J. E. CARNE, F.G.S., of the Geological Survey of N. S. Wales, 'Annual Report Department Mines, N. S. Wales,' for 1885, p. 145. In this case what he terms an oolitic limestone has incrusted the chain cable of the "Sirius," a ship which was wrecked at Norfolk Island in 1795. This incrustation of the chain with hard fragmental limestone has taken place between high and low water, though nearly at the level of low tide.

DARWIN refers to the formation of a similar calcareous sandstone, 'Coral Reefs,' Chapter I., Section 1.

† 'Proc. Camb. Phil. Soc.,' 1895–1898, vol. 9, p. 443.

The types of rock referred to under the head of L.5, L.6, L.7.A., L.7.B., L.8.A., and L.8.B. need little comment. They are all of detrital origin, formed by the action of waves and wind operating on the lagoon shores of the atoll. They differ from one another partly in composition (in some cases being formed chiefly of coarse gravel and shingle, composed of coral breccia, *Lithothamnion*, &c., and in other cases of foraminiferal sand), partly in age. The relation of these rocks to one another is shown on Plate 6, Funafara, Plate 7, Falefatu, Plate 9, Sections 9 and 10, on Plate 12, Plan and Sections of Mulitefala, Plate 14, Plan and Sections of Tebuka.

These plates show that the above formations mostly form curved belts, or parallel bands, on the lagoon side of the islets, being composed partly of material pushed around from the ocean front of the islets inwards towards the lagoon, but chiefly of sand driven landwards from the lagoon by waves and wind. The greatest elevation attained by the sandy deposit marked L.8.B., is at the north end of Fatato Islet, where it is 13 feet above high water. A feature specially deserving of notice in connection with these strata is that they are terraced, the older strata being a little higher than the newer, as shown in the Sections on Plates 9, 12, and 14. While in some cases the greater elevation of these inner terraces may be due to storms of exceptional violence, we think that, on the whole, the evidence is in favour of downward movement of the shore line.

As regards the deposit marked L.9.A., this is a recent gravel of the lagoon beach, composed of well-rolled and subangular fragments of coral and coral breccia, from about 1 inch up to 3 inches in diameter. This also is slightly terraced, the upper terrace being about 1 to 2 feet above the lower. Of an intermediate character between L.9.A. and L.9.B. is the fine subangular reef-rock rubble, which finds a temporary resting place on, or near the erosion zone O.2.C. of the reef platform on the ocean side. Some of this becomes imbedded between the coarser material of the Hurricane Bank, some is washed back into the channels on the reef-edge, O.L.10, and is swept over the reef-platform into the lagoon. We observed in the latter case that such subangular material, even when bedded in water subject to swift and variable currents, came to rest at angles at least as high as 40°, as at the channel into the boat harbour on the lagoon side of Pava Islet. One of us (Mr. SWEET) has observed that at the north end of Avalau the foraminiferal sand rests at an angle of 33°, even where bedded in the moving tidal water. The sand was chiefly *Tinoporus*, and, no doubt, the spines on the tests facilitate this sand coming to rest at such a steep angle.

The steepness of angle at which angular rubble from a reef will rest in water is obviously of interest in relation to the angle of the steep submarine slope bounding coral reefs. Such material, the natural angle of repose of which, in still sea water, may be 40°, or upwards, may attain a dip of 60° or 70°, or even become vertical through becoming rapidly cemented by *Lithothamnion*, *Polytrema*, *Carpenteria*, *Serpulæ*, *Polyzoa*, &c.

The deposit L.9.B. is formed for the most part of Foraminifera, amongst which *Orbitolites*, *Tinoporus* and *Amphistegina* predominate, together with fragments of *Lithothamnion*, and joints of *Halimeda*. The *Lithothamnion* sand is more plentiful on the western side of the atoll than on the eastern. As already pointed out by one of us, *Calcarina* is abundant, together with *Tinoporus baculatus*, at the islet of Motungie. Along the lagoon shores at the southern end of the atoll, the small lamellibranch, *Cardium fragum*, is so abundant that it constitutes nearly one-half of the beach sand. *Tinoporus baculatus*, however, forms the bulk of the sand in that area. At the southern end of the atoll, the whole of the islands are being removed, the sand being driven further and further on to the neighbouring portions of the lagoon platform. One of us (Mr. SWEET) is of opinion that the transference of material at that locality only needs to continue for some time, and a new sand island will be formed at that end of the lagoon.

The Hurricane Bank, O.4., is formed chiefly of torn-up fragments of the breccia pavement, together with fragments of corals, millepores, and *Lithothamnion*. This material is coarse and jagged above the level of high water, and, being more or less covered with black lichen, has the aspect of a bank of basaltic scoriæ. The fragments are from a few inches up to 1 or 2 feet in diameter. The Hurricane Bank either rests directly on the breccia sheet, O.2.D., or on some of the older lagoon deposits, such as L.6, L.7.A., &c. Though developed chiefly on the ocean side of the islands, a Hurricane Bank is also found in many places on the *lagoon* side of the eastern rim, especially in exposed positions like that of Funamanu and Funangongo, north of the Bua-Bua Passage, and at Falefatu and Mateika, to the south of the said passage. It forms the highest land in the atoll, that near the south-west end of Telele, where it rises 16 feet above high water. The material of the Hurricane Bank, like the older lagoon material, shows terracing in places, as at the north end of the islet of Fuafatu. (See Plate 16, and Section 1.)

The outer angle of slope of the Hurricane Bank is steep, being at 15°–30°, while inland the dip is more gradual, at about 10°. Inland it passes downwards into a "clinker field," of highly corroded fragments, which in turn blend with the solution area of the breccia sheet O.2.A. The general appearance of this inner part of the Hurricane Bank is shown on the following figure (fig. 18, from a photograph by Mr. SWEET). A point of special interest is the occurrence of a thin, but very persistent band of pumice pebbles, interstratified with the upper part of the Hurricane Bank. There can be little doubt that these were derived from the great eruption at Blanche Bay, in New Britain, in 1878. The local trader at Funafuti, the late Mr. O'BRIEN, told us, that during that year the Funafuti Lagoon, in places, was covered with rafts of floating pumice. The pumice layer in the Hurricane Bank is mostly from 5½ to 6 feet above high water (see Plate 9, Section 10), and it is interesting to note that the ordinary material, to a thickness of 2 to 3 feet, has been piled over the top of this layer of pumice since the date of its arrival. This was often

observed in sections on the ocean side, and the layer was occasionally seen outcropping on the inner slope of the Hurricane Bank, thus indicating a substantial recession of the latter since the deposition of the pumice. This pumice layer is repeated occasionally under similar conditions along the lagoon side of the atoll,

Fig. 18.—Inner part of the Hurricane Bank, south of Mangrove Swamp, Funafuti.

where it frequently forms a projecting shelf, the pumice pebbles being bound together by matted roots, chiefly of the cocoanut palm.

The following analysis of this pumice, by T. COOKSEY, Ph.D., B.Sc., is quoted from Memoir III., Part 1, Australian Museum, Sydney, "The Atoll of Funafuti," p. 77 :—

Hygroscopic moisture	·09
Loss on ignition	2·29
SiO_2	66·50
Fe_2O_3	3·21
Al_2O_3	16·84
CaO	3·03
MgO	1·03
K_2O	5·44
Na_2O	2·53
P_2O_5	trace
	100·96

A partial analysis of another pebble of a darker shade gave 60°·37 of SiO_2.

The general appearance of the Hurricane Bank facing the ocean, as well as of the reef platform at low tide, is shown on Plate E, the lower figure giving the living *Lithothamnion* zone, O.L.10, just awash at low tide, and next inshore the zone of dead *Lithothamnion*, O.3, succeeded by the old breccia sheet, and surmounted by the Hurricane Bank.

The deposit O.3 may be defined as a zone of dead *Lithothamnion* and foraminiferal rock, more or less of the nature of a breccia, with a smooth or slightly mammillated surface. It lies next inshore to the living *Lithothamnion* zone of the ocean platform, and is carpeted in places with small green algæ, replaced occasionally, as at Funamanu, by ochreous algæ. In addition to *Lithothamnion*, *Polytrema planum* has played an important part in building this stratum. A reference to Plate 17, Section on line C–D, by Mr. G. H. HALLIGAN, shows the general relation of this crust of dead *Lithothamnion*, *Polytrema*, *Carpenteria*, &c., to the old *Heliopora cœrulea* reef, O.L.1. This section may be taken as a type of what obtains elsewhere on the eastern rim of the atoll.

It will be noticed that towards the ocean edge of the O.3 zone the deposit rises first, then falls over so as to form a low rim about 6 to 7 inches above the general level of the small flat inside it. This flat, bounded seawards by the rim, is occupied by a series of long shallow pools at low tide. Accurate levels, taken with a 12-inch dumpy level, by Mr. HALLIGAN, show that the top of this rim is 2·82 feet above low water, whereas the bottom of the flat inside it is only about 2·22 feet above the same datum. A glance at the deposit which comes next outside, O.L.10, the living *Lithothamnion* zone, shows a repetition of the shallow flat and raised rim, the levels in this case being respectively 1·21 and 2·22 feet above low water.

We have formed two conclusions from this:—(1) That the rim of O.3 represents the former outermost rim of the reef platform at low tide, a position analogous to that now occupied by the rim of O.L.10, and consequently that the edge of the reef platform since the death of the *Lithothamnion* and other organisms forming O.3 has

(1) *Lithothamnion* Sandstone, Amatuku.

(*See p.* 78.)

(2) From the Living *Lithothamnion* Reef to the Hurricane Beach, Funafuti.

gained on the ocean by the width of the living rim, O.L.10, which, as shown by Mr. HALLIGAN'S section, is represented by the difference between 170 feet and 266 feet, that is a distance of 96 feet. This does not, of course mean that the edge of the reef platform of the atoll has advanced seawards, as the result of peripheral outgrowth, by a similar amount in the interval of time during which the belt O.L.10 was being reclaimed, but simply that as a result of the retreat of the sea-line as well as of the upgrowth, and perhaps to a limited extent outgrowth of O.L.10, an extra width of reef platform amounting to about 96 feet is now uncovered at low tide. It is not necessary to assume a combined upgrowth and outgrowth of more than a few inches in order to account for this widening of the atoll by 96 feet, as reference to Plate 17 will show that there are numerous piers of reef-rock, only a few inches below low water, lying just beyond the low water line, and consequently a downward movement of the shore-line only a few inches in amount, assisted by upgrowth and outgrowth of *Lithothamnion*, would considerably widen the reef platform.

(2) The death of the *Lithothamnion*, &c., in O.3 is due to a slight downward movement of the shore line amounting approximately to the difference between the general levels of the surfaces of O.3, and of O.L.10 respectively, which amounts to between 7 and 8 inches. Thus the downward movement, of which evidence has already been supplied by the raised *Heliopora cærulea* reef, the breccia outliers, the older terraced deposits of the lagoon side of the islets, &c., has probably been prolonged into quite recent time and may even yet be in progress.

It might be argued that the death of the *Lithothamnion* in O.3 might result from its removal from the reach of the sea-spray at low tide through the upward growth of the *Lithothamnion* of O.L.10 interposing a strip of reef at low tide between O.3 and the line of breakers. This explanation would be reasonable if O.3 were on the same level as O.L.10, but, as stated, it is not, O.3 being from 6 to 7 inches above the level of O.L.10. In view of the observations by Mr. FINCKH, that if the *Lithothamnion* be exposed for only one hour to sunlight above low tide, in a position where it is not bathed by the sea or sea-spray, it dies, and inasmuch as the dead *Lithothamnion* of O.3 is now exposed under the above conditions for fully 2 hours at low spring tides, it follows that *Lithothamnion* could not live now where we now find it at O.3 unless there were an upward movement of the shore line of perhaps about 6 inches, or some change of conditions which would admit of sea-spray being washed over O.3 at low tide. Hence we consider that we are justified in assuming that a downward movement of about 6 to 7 inches has probably taken place since the time when the *Lithothamnion* of O.3 was alive.

It will be noticed that on our geological map of the atoll a very large portion of the reef platform of the western rim of the atoll has been mapped in as O.3. It is quite possible that old *Heliopora cærulea* reef may underlie the O.3, there as it does on the eastern rim. It will be noticed that in Plate 17 Mr. FINCKH shows that some of the long channels which penetrate the living *Lithothamnion* zone O.L.10, terminate in

blow-holes in the surface of O.3. These appear to represent what were formerly open channels which have subsequently become roofed in, except at the blow-holes O.L.10. The rock thus indicated forms an almost continuous fringe around both the outer and inner edges of the reef platform, which Mr. HEDLEY likens to a carpet of dull crimson.* It is thus defined in our Index:—"Upper portion of the living *Lithothamnion* zone which is awash at low water of spring tides. This is chiefly developed at the edge of the reef platform facing the ocean, but is also present in places along the edge of the lagoon platform. On the ocean platform it forms conspicuous fringes at the edges of the channels and blow-holes and around the latter, where it is bathed by the spray, it forms numerous strong lip-like elevations or low mounds. Its surface is pitted, partly by burrowing echinoderms, and is tubercular, and usually slightly raised above that of zone O.3." This last statement is correct only for areas where O.L.10 is developed around blow-holes or channels, for as shown by Mr. G. H. HALLIGAN'S levels, the general level of O.L.10 is below that of O.3, and as already stated, in his section on Plate 17, the rim of O.L.10 is raised about 6 inches above the inner portion of the same zone. Since this was written Mr. F. CHAPMAN has shown that much of the material around the blow-holes and edges of the channels is *Polytrema* and *Carpenteria*, more or less interstratified with *Lithothamnion.*

Mr. A. E. FINCKH'S careful and detailed plan on Plate 17 gives an excellent idea of the shape of the boundary-line seawards of the living *Lithothamnion* zone. Its general appearance is shown on the lower figure of Plate E.† In the latter the O.L.10 zone extends from the lower edge of the photograph almost as far as to where the suction pipe from the diamond drill enters the water at a pool communicating with one of the channels. As is shown by Plate 17, the rock of O.L.10 runs out seawards in a number of irregular piers separated from one another by numerous channels. At low tide the sea rolls up these channels and blow-holes with considerable violence, and when this is accompanied by a general rush of water from a large breaking wave over the edge of the reef, the expression "running a traverse" acquires for those engaged on such a work a new and literal significance.

Further seawards below the level of low tide the *Lithothamnion* zone is continued in the form of irregular mounds, as shown in the "Detail Plan of Channel" by Mr. HALLIGAN on Plate 19. At first sight one is apt to form an exaggerated idea of the depths of these channels. Actual measurements by Mr. FINCKH shows that their depth does not exceed from 10 to 12 feet. A cross-section of five of them is shown on Plate 17, and a description of them is given by Mr. FINCKH in Section VI. He states that *Millepora alcicornis* grows sparingly on the sides of the channels

* "The Atoll of Funafuti," 'Memoir III.,' Part I., p. 13, Australian Museum, Sydney, 1896.

† This is taken opposite to the main drill bore-hole. In the foreground is the living *Lithothamnion* zone (O.L.10), with the head of one of the channels. Next inshore is O.3 (near the end of the suction pipe for the drill). Then comes the breccia, O.2.B., O.2.C., and O.2.O., surmounted by the Hurricane Bank.

together with *Pocillopora grandis.* It will be noticed that pebbles of reef rock strew the bottoms of some of these channels, but further seaward, according to his observations, the *Lithothamnion* rock is bare of detritus until the zone of live *Halimeda* is reached. The latter ranges on the ocean side of the reef, from 5 fathoms down to 45 fathoms. The structure of the reef below this level is described in Section VII.

In regard to the intricate succession of channels and piers forming the boundary of O.L.10, at low tide, we must inquire whether the former indicate channels of marine erosion, the piers representing incipient outliers, and the mounds beyond complete outliers, or whether the piers represent areas of more, the channels of less, active growth. If the latter hypothesis be considered, it may be remarked that when once re-entering angles are developed at the edge of the reef platform, through some portions of it growing out more rapidly than others, the heavy surf, funnelled in between the piers, would tend to erode back the bay, or at all events to check temporarily the further outgrowth of the reef at such points. Meanwhile as the piers are pushed further outwards owing to accretions of *Lithothamnion*, &c., the tendency is for these channels to be roofed over near the level of low tide, which is the zone of most vigorous growth of *Carpenteria*, *Polytrema* and *Lithothamnion.* The spaces left open further inland form blow-holes. Meanwhile, the sea-water surging to and fro in these channels, and sweeping reef *débris* backwards and forwards, continues to erode the bottoms of the channels, so long as the holes remain open, and thus admit of an ebb and flow of the water.

We thus hold the view, as the result of the study of the O.L.10 zone, that a very slow peripheral enlargement of the atoll is still taking place.* On the eastern rim of Funafuti this growth is dependent almost entirely on *Lithothamnion*, *Polytrema*, and *Carpenteria*. Mr. FINCKH'S experiments proved that the *Lithothamnion* can spread horizontally at the rate of 1 inch in 6·56 months, but the layer so formed was so thin as to be almost inappreciable, probably between 1/50 and 1/100 of an inch. As, therefore, it may take fifty years to form a layer 1 inch thick of the encrusting type of *Lithothamnion*, it is obvious that portions of this *Lithothamnion* rock which have a thickness of several inches must be of considerable antiquity, and the extension outwards of the atoll rim by this agent must be proportionately slow. Unfortunately, the presence of *Polytrema* and *Carpenteria* amongst the *Lithothamnion* was not detected at the time the experiments on rate of growth of reef-forming organisms were being conducted, so that more data are needed.

We may now pass on to consider the development of O.L.10 around the edge of the reef platform on the lagoon side. A remarkable feature in the lagoon reef platform is the low cliff, from 2 to 3 fathoms deep, in which it generally terminates. The edge of this cliff, together with a small portion of the upper surface of the reef platform, where it is awash at low tide, is encrusted with living *Lithothamnion.*

* 'Natural Science,' vol. 12 (1898), p. 174, "The Broadening of Coral Islets." By C. HEDLEY.

On the east side of the lagoon the edge of the cliff face is somewhat cavernous and friable, owing chiefly to the destructive work of burrowing organisms, such as gephyrean worms; the constructive growth of *Lithothamnion* and coral and *Halimeda*, checked on this side of the lagoon by heavy silting, scarcely availing to keep pace with the agents of destruction. On the western shore of the lagoon platform, however, the edge of the low cliff faced with O.L.10 is firmer, a fact due, no doubt, to the comparatively rapid growth there of both *Lithothamnion* and coral. Apparently then the small lagoon cliff owes its origin to a cause somewhat similar to that of the great submarine cliff bounding the atoll on the ocean side, viz., to the fact that the chief reef-building organisms grow most rapidly in comparatively shallow water, the tendency thus being for the upper portion of the atoll rim to grow outwards faster than the bottom. On the ocean side of the reef, however, the force of the waves and ocean current is sufficient to bevel the edge of the submarine cliff down to a level of about 30 fathoms, whereas, in the calmer water of the lagoon, no such bevelling has taken place; hence, in the latter case, the cliff falls straight down for 2 to 3 fathoms from the level of low tide, except in places where it has been obliterated by detritus swept lagoonwards over the reef platform.* Deposition of silt at its base has undoubtedly in places much lessened its height. This low submarine cliff at Funafuti is shown to a limited extent on Section 10 of Plate 9, where there are two drops close together of ½ fathom each. Near Pava and Fualifeke, however, as well as off Funamanu and Funangongo, the drop amounts to 3 to 4 fathoms.

The following table of areas occupied by the various types of rock at Funafuti, noted in the geological index, has been kindly prepared for us by Mr. G. H. HALLIGAN:—

TABLE of Total Areas, in British Acres.

Rock.	Area in acres.	Rock.	Area in acres.	Rock.	Area in acres.
O.L.10	545·430	O.2.D.	87·747	L.7.B.	174·871
O.4	215·678	O.2.E.	256·081	L.7.A.	90·319
O.3	1042·434	O.L.1	1002·104	L.6	33·865
O.2.A.	44·076	L.9.A. and L.9.B.	101·705	L.5	11·496
O.2.B.	176·010	L.8.B.	18·805	L.3	12·855
O.2.C.	32·689	L.8.A.	35·077	L.2.B.	7·383
				L.2.A.	3·973

* This cliff has also been referred to by Mr. STANLEY GARDINER, 'Camb. Proc. Phil. Soc.,' 1895–8, vol. 9, p. 424. Reference has also been made to the existence of a similar cliff on what was, doubtless, at one time the edge of the lagoon platform of Christmas Island, in the Eastern Indian Ocean, by Dr. C. W. ANDREWS ("A Monograph of Christmas Island (Indian Ocean), Physical Features and Geology," 1900, p. 13). He states: "The flat surface is similar to the reef flat of an atoll, *the inner cliff to the sudden drop of two or three fathoms which often occurs on the lagoon side of the reef flat.*" (The italics are ours.)

It should be explained that the above areas refer only to that portion of the atoll which was geologically mapped, which is about four-fifths of the whole atoll rim, as shown on Plate 1. The one-fifth omitted is all reef platform, submerged at high tide, and of this fifth, approximately one-half would be O.3; one quarter, O.L.1; about one-sixth, O.L.10; and about one-twelfth, outlying patches of various types of O.2 (breccia sheet).

With regard to the above areas, it should be noted that the old *Heliopora cærulea* reef, O.L.1, the area of the exposed surface of which is given as 1002·104 acres, certainly underlies the whole of the northern, eastern, and southern portions of the atoll rim, with the exception, perhaps, of about half the area denoted by O.L.10, that is, the portion of O.L.10 on the ocean side; and there can be very little question that the old *Heliopora* reef underlies a large portion, perhaps, the whole, of the western rim also, so that, in the area mapped, it is not unreasonable to assume that the *Heliopora cærulea* reef underlies the whole of it, with the exception, perhaps, of the area of the outer reef occupied by O.L.10, which amounts to about 273 acres. The total area of the *Heliopora cærulea* reef, in the portion mapped, which totals 3893 acres, would thus be $3893 - 273 = 3620$ acres, instead of 1002 acres, the area of the surface actually exposed. Of the area of 545 acres, accredited to the living *Lithothamnion* reef O.L.10, about one-half, viz., about 273 acres, may represent the area of the reef platform, on the ocean side, brought above low water level during the latest downward vertical movement of the shore line to the extent of about 6 to 7 inches. It may be noted that the total area of the breccia now exposed is only about 596 acres. To this may be added the amount hidden under a capping of newer deposits, which we estimate at about 704 acres. This would approximately raise the total area now occupied by the breccia to about 1300 acres.

The amount of material in the Hurricane Bank derived from the breaking up of breccia sheet is not equal to the amount of breccia which can be proved to have been eroded. The missing material, however, may be fairly accounted for by the amount removed in solution, which must be considerable, and also by the amount of material pounded up into fine sand at the foot of the Hurricane Bank. This material is partly blown over the top of the bank on to the surface of the islets, and is partly sucked back by the waves and tide into the channels on the outer slope of the reef.

Summary of the Geology and Past Physical Geography of Funafuti.

The facts already adduced show that the general shape of the original foundation of this atoll has been determined by some cause, probably volcanic action, or folding of the earth's crust, independent of the direction of the prevalent winds and ocean

currents. Since the determination of the broad outlines of the island its shape has been modified chiefly by :—

(A) Organic growth of the reef-forming plants and animals, notably *Halimeda* and *Lithothamnion* among the former, and foraminifera, corals and *Millepora* among the latter.

(B) By prevalent winds, which are respectively the S.E. to E.S.E. trade-winds and the N.W. monsoons.

(C) The ocean and tidal currents.

The convexity of the atoll on the eastern side and the concavities in its outline on the western side are thought to be due respectively to the work of the trade-winds being less destructive than that of the monsoons. The monsoons are frequently more violent than the trade-winds and tend consequently to keep open breaches in the reef, whereas the trade-winds are steadier and less violent, and thus have a less effect than the former in sweeping *débris* off the reef platform into the lagoon. Another likely reason for the atoll being more open on the western than on the eastern side is that if, as the magnetic survey seems to indicate, there is a nucleus of magnetic rock near the eastern side, that portion may be the older, and the reef may have started to form there earlier than it did on the west side. The two deep passages through the western reef rim, Te Ava Tebuka and Te Ava Fuagea, each about 25 fathoms deep, are evidently of considerable antiquity, as is shown by the great extent of the reef growth which flanks their sides for a distance of over a mile. At the point where the prolongation oceanwards of Te Ava Fuagea meets the 100-fathom line the soundings show evidence of a deposit about 300 feet in thickness. This is also in favour of that passage being of considerable antiquity. The lowest visible foundation rock of the reef platform along the whole of the northern, eastern and southern portions of the atoll is *Heliopora cærulea*, with occasional *Porites*. On the western rim *Porites* reefs abound, but none of the old *Heliopora cærulea* reef was observed there *in situ*, though it probably underlies the present horizon of the dead *Porites*, a view rendered highly probable by the occurrence of fragments of *Heliopora cærulea* at the base of the breccia sheet of the western rim.

Since the time that the *Heliopora cærulea* reef flourished just west of the Mangrove Swamp in the main island, a downward movement of the shore line has taken place of at least 6¼ feet, while in the case of the raised *Porites* reefs of the western side of the atoll, there must have been either a land-elevation or a sea-sinking of at least 9 to 10 feet. Prior, however, to this final downward movement (which is probably still in progress) there was a slight similar movement exposing the *Heliopora* and *Porites* reefs to the full denuding force of the waves, followed by a contrary movement of fully 8 feet, for we find that the surface of the old *Heliopora cærulea* reefs was for the most part covered with coral fragments, in a manner which could only have been accomplished by the denuding and disintegrating action of the ocean between tide marks, and it is necessary to assume a subsequent rise of the sea of

at least 8 feet to account for the fact that this disintegrated material became firmly cemented *in situ* by *Lithothamnion*. But this alga cannot live for more than about 1 foot to 2 feet above the level of low tide, and even in these cases it is necessary for it to be continually bathed by the spray, if it is to remain alive.

As much of this *Lithothamnion*-cemented breccia is now fully 2 feet above high water, and, as the tides at Funafuti have a range of about 6¼ feet, a rise of the sea of 6¼ feet would be necessary in order to bring the present top of this breccia sheet down to the zone of living *Lithothamnion*, the upper limit of which is about 2 feet above low-water spring tides, as just stated. At the south-west end of the islet of Telele an outlier of this breccia rises 10 feet above high water. Since this has corals *in situ* in it up to that level, and is cemented in the usual way, a rise of the shore-line of even as much as 14 to 16 feet would be necessary in order to submerge the summit at low tide, and so admit of the growth of the corals.

There is no definite evidence that any islets were formed during the growth of the old *Heliopora cærulea* and *Porites* reefs, but during the subsequent slight downward movement, followed by erosion of the preceding reefs between tide marks, the material thus eroded was probably piled up so as to form long islands. Subsequently these were submerged, and their materials spread out by waves and currents, and consolidated by *Lithothamnion*, &c., so as to form the breccia sheet.

This submergence amounted to probably about the extent of the maximum thickness of the breccia sheet, or at least 5 to 6 feet. A re-emergence of the atoll followed, the reef platform now consisting of *Heliopora* and *Porites* reef below and a breccia sheet above. By this re-emergence a continuous strip of land was formed from the Bua-Bua Passage to Pava, and probably from the north end of Mateika to Te Ava Fuagea. Isolated masses of breccia were also developed at Funafatu, and probably on other portions of the atoll rim between Te Ava Fuagea and Pava. The hard breccia sheet, brought now within effective range of the battery of the heavy surf, became completely cut through in places, the portions which best resisted denudation forming the hard substratum of the present islets. Meanwhile, masses of breccia would be dislodged from the ocean platform on the eastern side of the atoll, and from the lagoon platform on the west side, by the waves raised by the trade-winds, while, during the seasons of the north-west monsoons, the breccia would be attacked on the ocean platform of the west side of the atoll, and on the lagoon platform of the east side. By this means a double line of Hurricane Banks was thrown up both on the east and west sides of the atoll, so that, on both these sides, were raised an inner and an outer bank, which, classed on the basis of the agent which formed them, might be indicated in order thus, from west to east :—

Outer N.W. Monsoon Bank.
Inner S.E. Trade Bank.
Inner N.W. Monsoon Bank.
Outer S.E. Trade Bank.

Minor oscillations of the shore line followed, during which *débris* from the breccia sheets became overgrown by *Lithothamnion* and coral, as at Telele, and near Luamanife, on the main island, as well as in the case of the Amatuku conglomerate, and thus an upper crust of rock formed itself above the old breccia sheet. Finally, a downward movement predominated, and portions of the raised breccia sheet at the centres of the islets, where they were beyond the protection of either the inner or outer Hurricane Banks, would be dissolved away under the action of rain-water charged with humous acid, whereas the portion of the breccia sheet under these Banks would be more or less protected from corrosion by the overlying rubble and sand. Hence, towards the centres of the islets, a corrosion hollow would be gradually channelled out of the breccia, down to near the level of low tide, so that at high tide a strip of sea-water would occupy the centres of the larger islets, as is now the case. Such hollows would be bounded by strips of breccia of almost the full original thickness of the sheet. If, therefore, through denudation and erosion, operating from the ocean lagoonwards, the Hurricane Banks were driven in and pushed over the strips of breccia, and across the reef platform, a low wall of breccia would be left facing the ocean, marking the former foundation of the Hurricane Banks. Meanwhile, the detrital material of the outer bank, driven rapidly across the old corrosion hollow in the breccia, would find support against the strip of breccia preserved under the inner Hurricane Bank. This is precisely what has happened at Fualifeke and Pava Islets, where the outer wall of breccia marked O.2.D. (see Plate 13) marks the original position of the outer Hurricane Bank (see specially Section 1 of Fualifeke). What is, perhaps, even a more instructive case, is afforded by the islets of Amatuku and Mulitefala (Plate 12). The northern shore of Amatuku still holds the advanced position on the breccia line O.2.D., but Mulitefala Islet has been driven from the outer defence lagoonwards, its rallying point in this case being chiefly some masses of bedded calcareous sandstone, whose lagoonward dip shows that they were formed on the lagoon shore of the reef (see Section 2 of Mulitefala, Plate 12). It is, however, at the south-west portion of the atoll that this action is perhaps best illustrated. A long but interrupted line of breccia outliers runs from near Fuagea Islet to Avalau, and thence bends round to Motungie Islet (see Plates 3, 4, and 5, and particularly Section 1 of Plate 4 of Tefala). There has obviously at one time been a long island here from near Fuagea, down to as far south as Avalau, and from here right around to Mateika.

We return now to the consideration of the further growth of the islets of the atoll. Inside the Hurricane Banks blown sand and fine rubble gradually accumulated, and the islets became clothed with vegetation, and stocked with their present fauna. Meanwhile the deposit of silt at the inner angle of the main island gradually led to the death of the belt of *Heliopora cærulea*, which up to this time still flourished in the lagoon at this part of the atoll, though it continues to flourish luxuriantly in the lagoon (from a little below the

tion to receive them all without materially affecting its depth. The main island, however, though receding slowly on the ocean side, has certainly gained considerably in width, in the immediate past, through the deposit against its lagoon shore, near Fongafale, of foraminiferal and *Halimeda* sand, and there is every probability that it will continue to so gain in the near future.

We have already given many reasons, in the earlier part of this report, for our opinion that probably the atoll is slowly enlarging its periphery. It will be interesting in years to come to compare the outline of the reef at the main island, opposite the diamond-drill camp at the 1114 feet bore, with that shown on the carefully measured plan of Mr. FINCKH on Plate 17 and that of Mr. HALLIGAN on Plate 19. It will also be of interest to refer the Admiralty Bench mark on the Mission Church and the permanent marks fixed by Mr. HALLIGAN and Mr. FINCKH on the ocean and lagoon platforms of the main island to the level of low-water spring tides in the future. The *Lithothamnion* itself, in the neighbourhood of these marks where the latter were placed in the living *Lithothamnion* zone (O.L.10) should serve as a fair tide-gauge to indicate upward or downward movement of the order of 5 or 6 inches; for an emergence of 6 inches would probably suffice to kill a large area of the *Lithothamnion* now occupying the zone O.L.10 on the ocean side of the reef.

The surface geological evidence collected by us proves, in our opinion, that several oscillatory vertical movements of the shore have taken place in the immediate past at Funafuti, and we should not, therefore, be surprised if the evidence gained from the core shows that movements of the shore-line in both directions have occurred at Funafuti at earlier epochs.

With regard to the geological maps of the atoll, other than the portions shown on Plates 17 and 19, no pretence to more than general accuracy can be claimed for them. It is hoped, nevertheless, that they may prove of use not only in illustrating our present views as to the atoll's structure, but also for later reference, when possible changes on a larger scale in its physical geography and geology are being studied by future observers.

[*Note*.—In the manuscript of this Report, the Authors, to avoid prejudging the question whether the level of the land or that of the ocean has undergone changes, speak of the "positive" (*i.e.*, upward) and "negative" (*i.e.*, downward) movement of the shore-line. We have substituted the more familiar terms "upward" and "downward," but it must be borne in mind that if the land has risen, this corresponds with an apparent downward movement of the shore-line, and *vice versâ*.—ED.]

APPENDIX I.

Description of Small Islands of the Atoll.

FUAGEA.

Between the islets of Fuafatu and Fuagea, a distance of $4\frac{1}{2}$ miles, the platform, which is discontinuous, is devoid of land except for two sand-banks. One of these, a mile or more N.W. of Fuagea, is small, and has a few bushes on its summit; the other, much nearer Fuagea, is long, low, and narrow.

The southern half of the western rim of the atoll of Funafuti is not disconnected and broken up as is the northern, but is almost continuous, being of considerable width across, and conspicuously so opposite, *i.e.*, west of the Mateika and Bua-Bua channels. Here the current and wind, for the greater part of the year, cause the water flowing from the ocean through these wide passages and across this narrow part of the lagoon, to impinge on the lagoon side of this western reef. At this place the reef has developed to its widest, forming at about the middle of the part so affected quite a considerable projection lagoonwards. Here the extra width of the reef is sufficient to permit an island to be formed (Plate 1).

This island, called Fuagea, meaning "sand place," has been compared to the shape of a pear, with the stem to N.N.W. (Plate 3); it is essentially a sand island thrown up or widened by the wash of ocean and lagoon converging at its site. The distance between this island and the ocean margin of the reef on which it stands is greater than the ordinary width of the reef north and south of this point, so that it would appear that the island owes its existence to the unusual width of the platform here. This acts as a very wide breakwater; on it there are, moreover, several bosses of *Porites* and low breccia scarps which assist also in breaking the great force of the waves during the high tides and strong westerly winds, that occur from December to March, before they reach the present site of the island. On the other hand, on the lagoon side, though Fuagea is directly in the course of the S.E. currents as they come rolling in through the wide and deep passages above referred to, yet, as the island occupies a position a considerable distance from the lagoon reef edge, it has been possible for it to retain this position, though its outline is subject to variation. The island itself is thickly wooded with green cocoanut trees, especially at the south end, while to the north the vegetation diminishes in height and density before its limits are reached.

At the time of my visit, after eight months of the S.E. trades, a long point of sand (the stem of the pear) projected to the N.W. without any vegetation whatever. To the south or larger end of the pear, the matted roots had been undermined and the trees, cocoanut and pandanus, had fallen; some were still attached to the land surface by numerous small matted rootlets, though their tops were lying on the beach. This beach was here unusually steep and short, with an undoubted erosion outline, rising sharply out of the water to a height of 2 to 4 feet. In a less marked degree, all along the S.E. portion of its length, and on the opposite or S.W., material is continually being removed from or added to the beach. About midway on the east side is a soft coarse sandstone formed chiefly of *Lithothamnion*, such as is to be found on adjacent portions of the beach; it dips roughly 9° eastwards, not, however, agreeing with the beach near by either in the direction of strike or angle of dip.

Where it projects beyond the line of the present beach this sandstone is being eroded, and being but slightly coherent, is fractured as it is shifted and so becomes broken up into fragments, which help to make up the present beach. This is probably the cause of the increase of *Lithothamnion* in the lagoon beach at this point, compared with what it has elsewhere on this island. There is a perceptible increase in the admixture of *Lithothamnion* on the ocean side as compared with the lagoon one, except near the site of the *Lithothamnion* sandstone on the latter

No dense sub-base to this island overlying the platform was anywhere observable; but there does exist, much nearer the ocean margin than the present island, in addition to the *Porites* bosses, in a few places over a small area, a very thin breccia-like covering scarcely distinguishable from the platform itself.

The whole surroundings of this island indicate that, as already stated, its existence is due to the exceptional width there of the platform and to the slight protection of the few *Porites* and remaining low breccia elevations, though even this is not sufficient to insure its stability. The few masses of *Porites* with the patches of breccia, while they mark the site, also represent the now almost obliterated foundation of the former island which has been eroded, the finer material being driven further and further lagoonwards till it has reached its present position, which serves to mark the distance it has shifted from its earlier site. It also suggests that any extension of this earlier island or of others existing either north or south, or both, would probably have fared similarly; but to have removed so far as this would have carried them beyond the platform, into the lagoon, which is undoubtedly what has happened. Now it is to be observed that nearly all along the western rim and southwards, the Admiralty Soundings indicate unusually shallow water from close up under the lagoon reef to a varying distance out from it, thus accounting for the material removed from the islands which at one time almost certainly occupied positions on this reef.

Except in the case of channels, the spaces between the islands are occupied by a continuation of the reef platform on which they rest, while here and there along the middle or outer portion of these platforms on the west side of the atoll, lines of low scarps exist corresponding with those on the wide platform north of Mulitefala, with pinnacles and a thin worn and rugged breccia sheet, in some places not yet all removed. Beside this, there are blocks of blackened coral to be seen at intervals all along, now numerous, now rare; these, the so-called "negro-heads" of some writers, can be examined at many points. On this side they appear to be chiefly *Porites*, which are generally *in situ*; and while present at other parts of the atoll, their presence is often conspicuous on the western reef platform, from the comparative absence of land. Here only a few of them were examined, but those so tested were, as usual on this side, found to be big bosses of *Porites* firmly embedded in and projecting through the platform as well as through the breccia also where it is still present.

There can, I think, be no doubt that these low scarps and pinnacles with the *Porites* bosses and stumps are the lingering remains of the foundations of former islands. It will be noticed that only where these rocks are numerous or when there is a considerable mass of the breccia sheet not yet eroded away, will there be an island or a sand cay, each of which rarely exists without one or other of these defences, or else a wide expanse of reef platform between it and the ocean.

TEFALA.

This islet, like Fuagea, stands well up above the waves, its highest point being about 9 feet above high water. It supports a fair number of cocoanut palms, though it is conspicuous for its Pandanus (Falā) trees, whence its name. It is free from fallen trees on the margin of its surface, and is not so subject to variations of outline as Fuagea, besides being more sheltered than it from rough seas (Plate 4).

The material of its upper portion is throughout like that of the last islet, sand and small fragments, with the addition of some larger old coral fragments scattered on the surface, and accumulated in some quantity on a part of the S.W. beach. Its surface is even more flat than in the last, fewer undulations being present, though three or four are prominent at the east and S.E. portion. This part is exposed to the force of easterly gales across the lagoon—as my experiences there, limited as they were, sufficiently proved to me. Such gales as can exert their full force on the island, across the lagoon and over the narrowest part of the lagoon reef on to its beach, are, however, not common, but that they do occur is proved by the undulations on the upper margin of the island, and the sectional outline

of the beach. S.E. of the island a projection of the platform into the lagoon for several hundred yards protects it in that direction.

At the base of this islet and resting on the ocean platform is a thin sheet of breccia which continues around the S.W. and north of the islet, covering the platform, but worn to a rugged outline by the action of the waves. Resting unconformably on the inner edge of this are a series of more or less indurated fine and coarse sandstones (L.3. and L.2.A.) and finer breccias (L.2.B.), dipping N.E. towards the island and the lagoon at an angle of 5° to 8°. The finer breccias (L.2.B.) are also exposed at the S.E. corner on the lagoon side of the islet, under which it appears to extend. Beyond these sandstones, seawards, and projecting upwards through the older breccia, are large and small bosses of *Porites*, a few of which corals have been noted at the last islet, and were seen, though rarely, on the platform between that islet and this. Here, however, they have suddenly become much more numerous, while to the S.W. they are abundant, though smaller than those seen at Fuagea, averaging here 2 to 3 feet in diameter by 1 to 3 feet in height above the platform and breccia, some being nearly or quite up to high-water level. They are bounded on the ocean side by the corrosion zone, and become less numerous immediately to the south of the islet. Here either a space remained as a channel, which we think probable, during the growth of the *Porites* and the subsequent breccia deposition, or both the *Porites* and breccia have been subsequently eroded.

The position of Tefala on the reef is much nearer the ocean margin than any islet on the western reef between this one and the northern one of Te Afualiku, over 10 miles distant, and the undoubted cause of this difference is the protection Tefala receives from the presence of the remains of the breccia sheet and of the *Porites* bosses, together with the more or less indurated coarse and fine sandstones and newer breccia on its western side. The persistence of the older breccia here is due to the great number of the bosses of *Porites*, which is the most enduring of the coral masses found on these islets. Useful as it is, the protection afforded to the islet is not, however, equal to what it once was before the breccia was corroded and denuded, and from this it would appear that the *Porites* and older breccia must have supplied first a base for an island, and now a good protection to a later stage of its existence since it has been shifted nearer to the lagoon. This transference of material from one position to another is shown by (1) the dip of the sandstones, and (2) the fact that those now nearest in to the beach on the ocean side of the islet, but dipping under it, are, in one or two places where they have been recently uncovered, higher than those further seawards, although they are softer than the latter. From the contour of the breccia and the general strike of the sandstones, it would seem probable that the latter were laid down in and sheltered by a small bay on the lagoon side of the earlier islet. We must, therefore, reasonably infer that the islet is still moving lagoonwards, as, indeed, is inevitable from the gradual erosion of elevated obstructions on the platform.

On this islet the descending order, chronologically, of deposition of the several formations appears to be :—

10. L.9.B. and O.4.
9. L.8.A. Recent, but not covered with vegetation.
8. L.7.B. Older, sandy and loamy soil.
7. L.6. Sandy and loamy soil.
6. L.3. Newer *Lithothamnion* sandstone.
5. L.2.B. Newer reef breccia.
4. L.2.A. Old lagoon conglomerate sandstone.
3. L.3. Nullipore sandstone.
2. O.2.E. Breccia sheet.
1. *Porites* and O.3. Dead reef, now forming the reef platform, probably O.L.1.

The history of this island, indicated by the order and position of its deposits, is as follows :—On the platform, over and including the present breccia remains, existed a breccia sheet of similar height to

that in other parts of the atoll, and strengthened by the presence of many *Porites* masses, which have persisted since before the formation of the older breccia. This was attacked by the waves, was eroded and broken off, and with any new coral, *Lithothamnion*, foraminifera and molluscan shells was thrown up, forming a complete islet as now seen on many parts of the atoll. On its lagoon side was a considerable indentation in its breccia, forming a bay; into this the sand and *débris* from the islet were driven, and in time hardened, forming the compact sandstones (L.3.) dipping lagoonwards. These were then further covered and protected by more waste from the same islet being thrown over it; the waste of this again proceeded, till by slow degrees the first islet disappeared from its old site altogether, and appeared further lagoonwards. It thus shifted more and more till the breccia, once the foundation of the islet, is now much eroded, and the sandstones once laid down lagoonwards of the islet, reappear on the ocean side and become also subject to erosion.

TE FALAOINGO.

Between Tefala and this islet (Plate 4) occasional black-topped pinnacles of rock are to be seen which pierce the waters that cover the long tidal platform between its central axis and its ocean margin. These, which are the tops of *Porites* and breccia pinnacles, increase as this islet is approached, until within a third of a mile north of it they become very much more numerous, occupying nearly the whole of the extent of the platform, and extending southwards to the next islet. On its first appearance it is suggestive of an extensive area of massive ruins, over the most of which, as the land has subsided, the sea has rolled and effected a general but rude levelling. The peculiar circular masses of coral raised mound-like in the centre, with concentric and rudely radiating joint-like markings, have the appearance, at first sight, of having been hurricane stranded. These are *Porites* blocks tilted slightly to the sea as they grew, and embedded in the breccia mass, as though set in concrete. The latter contains only an occasional fragment of *Porites*, and, except for these broken pieces, most of the *Porites* masses are *in situ*. There is a vast number of these great blocks here, ranging up to 7 or 8 feet in diameter, and forming the platform level near the ocean margin, to 4 feet above high water, near the islet. They protrude through the main mass of the breccia which occupies the spaces between the bases of these *Porites* blocks, and has here, as at other places, yielded more rapidly to the action of the waves than the *Porites* masses, so that the latter are left standing in relief.

Very little *Heliopora cœrulea* was seen, and this not *in situ*; should it exist, as I think probable, it is obscured by the breccia. A little new *Heliopora cœrulea* was seen with some other coral fragments among the breccia and between the *Porites*. Unworn new coral of any kind is rarely thrown up here. This may be accounted for by the rugged character of the floor of the platform, and the upstanding *Porites* blocks and breccia which would intercept and break up any wave-borne object. What little there is, is chiefly broken pieces of the yellow *Millepora*. The outer sea-platform differs greatly here from the average sea-platform in width and form, the width being much less than usual, and the "water channels" of the outer reef more numerous and penetrating further into the platform than commonly; there is a much wider corrosion zone (O.2.B.), which is very much nearer the ocean margin than usual, there being scarcely any of the worn platform zone (O.3).

The islet of Te Falaoingo is situated farther from the ocean face of the platform than Tefala, but not so far as Fuagea and the other western islets to the north of this. Its present existence as an islet is undoubtedly attributable, as in the case of Tefala, to its being sheltered from the strong westerly gales by the presence on the ocean platform of the protecting breccia and the masses of *Porites* acting as a breakwater. The islet is in form roughly an irregular oblong. It is composed of a thin layer of foraminiferal and *Lithothamnion* sand mingled with a little beach *débris*, shells and pumice, &c., the surface of which is about 4 feet above high-water level. The islet is attacked by the surf at every

conjunction of westerly winds and high tides, while the sea has invaded and divided it into two, thus giving rise to a channel, through which at certain times water is flowing.

The lagoon side, however, of Te Falaoingo must have remained almost stable for some years, as is proved by the size of the trees, though, on the west side, clusters of the "Ngie" trees (*Pemphis acidula*), some distance out, mark the comparatively recent boundary of the island oceanwards: this boundary has now receded in places to half the width of the island at that time, but without affecting its lagoon boundary to any considerable extent during the recent past.

It is now, with its few cocoanut trees and shrubs, little more than the narrow remnant of what it evidently has been. Probably the small sand cay to the north of it represents the shifting remains of a long since detached extension of this island, which itself is now slowly approaching a state but little superior to it. The *Porites* and breccia sheet which surround this islet and the sand cay are evidently continuous under it, as the *Porites* are seen in a few places appearing above the surface of the islet. The lagoon platform on the east side of the islet, though rugged, is very much less so than is that on the ocean side, the forces producing corrosion having evidently been less violent here than on that side.

The history of Falaoingo is comparable to that of Tefala in so far as the *Porites* blocks, breccia sheet, and the shifting of its finer material lagoonwards is concerned. The former islet, however, is without the fine and coarse sandstones and newer breccia formations which constitute so conspicuous a feature on the latter.

TUTANGA.

The *Porites* blocks and breccia sheet noted at Te Falaoingo are continuous to and around this islet. Between the two islands are a tidal channel and a boat channel, through both of which the water often runs rapidly, and the latter must be forded, even at low tide; in each, small corals of two or three species are living. The superior height and luxuriance of the vegetation on this islet makes it a conspicuous and beautiful object both far and near; though small in area, it eclipses in the above respect many of very much larger extent around this S.W. corner. Its damp moss-covered blocks of coral and breccia, with their numerous ramifying caverns, and dissolving clinker-field-like floor, are evidently well suited to its flora.

The base of this islet appears to consist of the same formation as that surrounding it, but it differs from most other islets, especially on the western rim of the atoll, in that the foundation of breccia and *Porites* in its centre is dissolving. These attain a height from 3 to 5 feet above high water, and between them there exist deep pits with rugged sides and bottom, and of greatly varying depths, communicating with each other by equally tortuous subterranean passages, in which the water rises sympathetically rather than simultaneously with the tides. The whole is sheltered by towering cocoanut trees and closely veiled by luxuriant tropical ferns, shrubs, creepers and thickly growing mosses; rendering clambering over and through it (walking is out of the question) and the examination of its vegetation-covered subterranean recesses both difficult and hazardous.

It is certainly a typical surface solution area of its kind, one that has its less pronounced analogues on some of the islets in occasional solution areas, usually met with between the so-called clinker fields of the ocean side and the sand deposits of the lagoon side, though occasionally in the midst of the former. Still it is undoubtedly an area where the surface vegetation is exercising a very active and continuously corroding influence which, while it abstracts nutriment from the rocks, also renders them more susceptible of the dissolving effects of the waters from above and below. The most active solution appears to be limited to the central part of the islet, and as the lagoon side is approached, its intensity is gradually but decidedly reduced till it appears nearly or quite to cease. The foraminiferal sand and small fragmental material forming the surface of this east side (as well as on the north and south) probably obscures a continuance of the *Porites* area which can be seen outside it, and which occurs so markedly in the centre of

the islet. The *Porites* blocks, though fewer in number here, appear through the beach sand on the lagoon side, while the sand seems to retard greatly, even if it does not prevent, the process of solution. On the west or ocean side of this islet is a small but rugged clinker field whose outer boundary is also the limit of vegetation. Beyond this is the Hurricane Bank, which is succeeded by a depression along its side many yards wide and enclosed by an outer and smaller ridge forming a loop. The enclosed depression is carved out of the very hard and dense breccia sheet, and contains no *Porites* except as low stumps; it also follows exactly the shape of this side of the islet with which it is conterminous.

Apart from the central solution area in this islet and a great accumulation of sand at the lagoon side of the northern end of this islet (*vide* Avalau), there is only one feature in its history distinguishing it from the islets above described on the western side—namely, that of the depression on the ocean side of the islet. Probably this represents the site of an earlier solution area equally or even more intense than the present one in the centre of the islet. If so, the area affected by solution is receding from the ocean side, and its Hurricane Bank has been driven lagoonwards, so that an earlier position of this is marked by what is now the outer low ridge.

TENGASU AND TEAFOAFOU.

The general characters observed in the platform at Te Falaoingo and Tutanga are continued on to Tengasu (Plate 4) and Teafoafou (Plate 5).

Immediately to the south of Tutanga, and therefore between that and Tengasu, is a good boat channel; south of this there is a gradual but marked reduction in the number, and especially in the size of the *Porites*. Passing still further southwards, they continue to diminish both in number and size, till very many are only about 2 feet in diameter, and less than that in height. They are, however, similarly situated in relation to the breccia. The effect of the reduced obstructions to strong westerly winds, caused by these modifications in the conditions, is shown in the character of the islets. There can scarcely be said to be any Hurricane Bank on either side of them, unless the belt of fragmental material can be so regarded. This, however, is not higher than the islet itself, the platform rising gradually to the highest level of the land, with but a slight step upwards where the loose fragmental material commences. On the lagoon side, the width of the platform varies considerably, though it bears some little relation to the form of that side of the island; while the sand flats invade and cover a portion of the breccia floor on this side. The hardy Ngie trees stand in places well out from the island on the eroded breccia towards the ocean platform, with their roots firmly grasping the breccia floor, resisting every advance of the invading waters, and marking an earlier boundary of the now receding islet. They also serve to break the force of the waves and surf, and furnish a temporary shelter for loose fragments of coral that may chance to be driven landwards. The buffeting of the waves seems to increase rather than to reduce the vitality of this tree, till some unusual force—perhaps a large worn mass of breccia or coral driven by the waves—breaks it off short at the roots, when it is swept away. During high tides the billows roll up to and over some parts of the island of Teafoafou, making surface breaches, from which the vegetation has been in part or wholly removed; the soil being reduced at nearly every such attack faster than it can be replaced. Then the higher vegetation, receiving insufficient support and nourishment, gradually sickens and dies, or is carried away, soil and all, by an unusually fierce gale. Thus it is being slowly divided into several parts, just as it has been separated from Tengasu. Near each end of Teafoafou it is flat-topped, with much pumice nearly covering small areas, on which vegetation grows more large and healthy. This, with the luxuriant vegetation of Tutanga, and of one part of Tengasu, bears evidence of what it probably was throughout, before the soil was subject to the incursions of the sea. A small area in the north end of Teafoafou, from which the material of this end of the islet had apparently been almost, if not quite, removed by the

action of the sea, has comparatively recently been surrounded by a sand beach thrown back from the lagoon. (*Vide* Avalau.)

The history of this corner of the atoll is nearly a repetition of that observed from Tefalaoingo to this point. The present condition of these two islets, Tengasu and Teafoafou, though the latter is much larger in area, closely resembles that of Tefalaoingo (*q.v.*), with this difference, the ocean side of Teafoafou is not driven back to such an extent as at Tefalaoingo, so that the earlier ocean boundary is still seen in a less eroded breccia sheet, with its clusters of Ngie trees; while the island itself is much wider than is that of Tefalaoingo, notwithstanding the less height of the *Porites* bosses.

AVALAU.

This island (Plate 5) is pleasant in appearance, its cocoanut and other trees attaining a height and vigour fully up to the average. Its surface is moderately level, standing somewhat higher above high water than Teafoafou, and is situated well back from the ocean bed of the platform. The present island has not been greatly disturbed by invasions from the sea, though on its ocean side it has suffered in some degree. The sea rolls over the breccia, which has been eroded to a gentle slope from the ocean platform (O.3) to the beach, obstructed by only two or three low and narrow breccia scarps, and but few *Porites* blocks; these not being nearly so large as was observed further north. As a result, where the direction of the monsoons is at right angles to the beach, the sea has scattered for a considerable distance into the islands whatever has been thrown up, so that it now exists as a wide but mild form of clinker field. Further south, along its west side, where the seas strike it obliquely, and can escape southwards, a normal Hurricane Bank begins to be developed, till at the south-west corner it becomes of moderate proportions. Along the southern end the Hurricane Bank is steep, and the clinker field rugged. These also continue, till near its northern end, along the lagoon side, though in much reduced proportions, and it is then succeeded by a sand bank scarcely higher than the general level of the island, and projecting northwards.

For a considerable portion of its northern surface, Avalau is formed of sand, *Lithothamnion*, and other fine fragmental material, presenting in its central portion a moderate area of level, open floor, with but few trees. Here, near the centre of the island, and in this material, is the native well, the sides of which exhibit a somewhat similar formation to that in which those at the main island have been made; this well supplies—after rain—water used by the natives for drinking purposes when their other sources of supply fail. But since the bottom of it, as like those of Fongafale, is much below high-water level, the water disappears at every fall of the tide, and is forced back with the rise, thus being always more or less brackish. Around the area which is occupied by this finer material, is one in which more coral rubble, and some pumice, is intermingled, and here the trees are more numerous, and thrive much better than they do in the *Lithothamnion* material.

Dividing this island from Teafoafou is a channel through which the tidal waters flow till the tide is quite low. This channel bounds the north point of the projecting tongue-like foraminiferal sand bank, which is 3 feet high above the platform, and partly submerged at high water. The slope of this bank was inclined, when we were there, at the angle of 33°, although it was not only submerged, but the outgoing tidal waters were flowing past it. This sand beach, and those at the north of Tutanga and Teafoafou, appear, from their direction and shape, to have been determined by the action of the waters of the lagoon when agitated by reason of high tides and strong winds from the south driving the sea across the reef between Motungia and Avalau. This produces a scour along the lagoon side of Avalau, Teafoafou, and Tutanga, and carries the finer material northwards, till it finds shelter at the northern end of each of these islands. Here it is deposited, and now forms extensions, which, however, the high westerly seas periodically disperse, much of it, no doubt, finding its way into the lagoon.

The lagoon platform east of this island is very much extended, beyond the ordinary width of lagoon

platform along the adjacent islands, by a wide sandstone deposit, passing in parts into a fine breccia, which overlies first the lagoon conglomerate (L.3), and then the ordinary reef breccia. The first-named of these appears to be somewhat unconformable to the second, and both are decidedly so to the third, and all again to the fourth; the sandstone and fine breccia dip towards the N.E. at an angle of about 6°, the fine breccia resting on the sandstone, this on the conglomerate, and this on the reef breccia. It is to be observed that the strike of the two upper deposits agrees approximately with a line drawn from the south end of Teafoafou to the next islands, Motungia and Nukusavalivali, but does not conform to the outline of this side of the present island nearest which its lower beds rest. It would appear quite improbable and without support from similar phenomena observed in any part of the islands of this atoll, that these sandstones could be laid down as we now find them, with the scour usual at this locality, which is at work at high tide during every strong S.E. wind, and is sufficient, as we have seen, to drive away all the finer loose material along this and the neighbouring islands, and to deflect it into the shelter of the north ends of each, where it is deposited as sand banks.

The deposition of this newer sandstone, in my opinion, undoubtedly requires the shelter of some higher land on the reef south of it than the present reef affords. This would at once provide from its waste (1) the material of which the sandstone is formed; (2) an inclined bank along the direction of its strike on which it could repose, and (3) a protection from disturbing incursions from the sea, and so (4) the presence of calm waters which our observations on this atoll show to be essential to the laying down of recent sandstones. To the south of these sandstones the reef breccia and conglomerate are uncovered for a considerable distance, the sandstone having apparently been removed. Before the south of the island is reached, a more or less sharp step occurs in the conglomerate and breccias, varying in height from 2 feet 6 inches till it is lost. Its outline is roughly parallel, with a shallow depression commencing between this and the reef south of this island, and deepening as it extends westerly into the lagoon. This depression is now the channel to which gravitate the first waters which, at the rising of the tide, pass over the reef in its vicinity and that circumstance has doubtless contributed to its excavation. This, with the attacks from the sea during high tide and strong winds from the S.E., *i.e.*, from the direction of the prevailing wind, and the scour so produced, will go far, when the outer contour of the reef is remembered, to account both for the erosion of the depression, the partial removal of the sandstones, conglomerates, and breccias, and the creation of the step or low cliff.

MOTUNGIE.

Occupying the extreme south of the atoll, between Avalau and Motungie, is a wide and long reef, in width resembling that occupying the extreme north of the atoll. On its western portion, and near to Avalau, there is but a comparatively thin sheet of much eroded breccia, though here and there thicker portions occur; still in a few places it is very much thicker. The *Porites* masses have become less and less as we have approached this point, and have now all but ceased to exist. Not far from midway between Avalau and Motungie some remnants of the breccia sheet attain a height of a foot above high water level. Sweeping round from Avalau seaward from these higher masses and on to Motungie, are low breccia scarps, which indicate the site of successive boundaries from whence the breccia sheet has been eroded. In the same way the remaining high masses indicate the level which it must have reached, and has probably much exceeded.

The highest of the long breccia scarps is far back on the platform, and is plainly one of the last outliers of the breccia sheet, having till now resisted the unceasing attacks of the waves, to which in other parts it has yielded. Behind or on the lagoon side of this outlier a cliff is formed, 6 feet high, and ending in a depression in the breccia, in which a pool of water remains at low tide. Behind this and beyond the breccia covering the reef there lies a deposit of moderately coarse rubble driven into the shallow waters of the lagoon.

In the thin covering of breccia, with its flatter included fragments lying almost horizontally or but slightly if at all inclined and that towards the sea, we see the remains of the foundation of the island that provided the material for and sheltered the formation of the soft conglomerate, breccia and sandstone. The rubble bank indicates the destiny of the material forming the islands which we now see. This also shows clearly the effect on the deposition of all wave-shifted rubble on the reefs, wherever the obstruction is not sufficient to deflect the waves upwards, *i.e.*, when their power is too great to allow the material to be piled up as Hurricane Bank, and they carry it onwards. Seeing that this corner is subject to attack from all the prevailing winds that blow, whether they are from the S.E., W., or N.W., the great erosion of the reef breccia sheet here is not a matter for surprise, and this with the absence of the supporting *Porites* is no doubt the cause why both it and land disappear at this corner. It should be observed that the further one goes east on this reef, that is to where it can act at the exposed south-west corner as a breakwater from the heavy seas driven by the N.W. and W. gales, the less has the breccia sheet been eroded, till it becomes, under the additional shelter afforded from attacks from the S.E. by the reef near Nukusavalivali and by that island itself, the foundation for the islet of Motungie. This being so, the presence of an increasing thickness of reef breccia and also of the latter islet is due to the wider extent of shallow reef over which the breakers have to roll before reaching it, reducing their force and thus rendering it immune from the more severe attacks. The breccia has therefore been preserved from total erosion, and assists in turn, with the before-named protection of Nukusavalivali, to favour the deposition of a sand bank on that and Motungie (Plate 5).

Motungie, "Island of the Ngie tree," is suitably named, as it is but a thicker mass of breccia than those we have just left, surrounded by the Ngie trees with a few small cocoanut trees which have been planted on the surface of the islet. Under their shelter and that of the long cross-reef island Nukusavalivali, the foraminiferal sand has found a lodgment, and now forms, at about 5 feet above high water, a surface of less than a quarter of an acre, sloping away on all sides to the breccia. To the west of it, and on a continuation of this ridge of breccia, a tongue of sand extends under shelter of this and the next island; and on it I first found the most perfect *Tinoporus baculatus* which I had up to then discovered on any part of the atoll. On almost all other parts the small spines surrounding the test of this species were usually more or less worn off, but here the majority appeared almost perfect, indicating that the source whence the recently dead forms came could not be far distant. Between this and the next island is an eroded channel through which the water flows into and from the lagoon when between 1 and 2 feet above the platform.

NUKUSAVALIVALI.—"The sand (island) that goes the wrong way."

The meaning of this name was variously rendered to me by the best interpreter on the island (from dictation by the King), as follows—"All same big fool island, he not know which way to go"—"he go wrong way." On this atoll the longitudinal axis of an island usually agrees more or less closely with that of the reef on which it stands; but here curiously enough this order is reversed, and Nukusavalivali crosses the reef at approximately right angles. This peculiarity the natives had shrewdly observed and thought of sufficient interest to indicate by its name. Its apparently erratic position is, however, due to a very simple cause; it is an island whose surface is composed variously of foraminiferal sand and fine and coarse fragmental material mingled in the upper part with pumice pebbles which in places are quite abundant. This rests on the eroded breccia sheet, which is thinner on the lagoon than on the ocean end, being here about its usual height; that is, about 1 foot to 1 foot 6 inches above high water. The summit of this island at its ocean end is protected by a Hurricane Bank, succeeded by a narrow clinker field, and its cocoanut trees are healthy and flourishing. Its eastern side is being severely attacked, as during the season of S.E. winds at high tides and strong gales the seas breaking over the wide breach now

existing east of it, impinge on this side and undermine the bank, which is made vertical for a height of 3 feet. Thus the trees fall on to the beach, with their matted roots forming a mass a yard or more in diameter, and enclosing from 6 to 12 inches in thickness of sand, pumice, bits of coral and breccia; while the matted roots of the other vegetation of the surface in some places project as a shelf, till this also becomes too much undermined to hold together, and then they also break away. In that way this side of the island is being eroded all along and carried into the lagoon, thus determining the eastern outline of the island.

Close to the west side of the island, and between it and Motungie, a channel has been eroded through which the tide commences to flow to the lagoon soon after it has covered the tidal platform, and that has determined the western outline. Its present length, therefore, simply indicates a portion of what was once its width before erosion by the waves had cut a channel on either side of it, increased by the addition of the foraminiferal sand accumulation at its north or lagoon end.

That this is so, is shown by the eroded long scarps previously mentioned in the base of what was the breccia sheet, which here and there roughly, but fairly, indicate its oceanward outline. These scarps, which sweep round from the south of Avalau in more or less of a curve, are continued by some further outliers to near the point of breccia south of this island, and then on to the island beyond (Motuloa), the only interruptions to this line being where the breccia curves in to form the boundary of the breaches and channels which are mentioned above. On the lagoon side also, if a concave curve be drawn to the lagoon side of the eastern three-quarters of Motuloa and extended to Motungie, that will pass quite close to the north end of this island; this further suggests that there is nothing unusual or erratic in the circumstance of the longer axis of Nukusavalivali crossing the reef, as it merely indicates a portion of what its width has been at an earlier period.

To the east of this island between it and Motuloa the wide breach before mentioned is actively corroding the base of the still opposing breccia: through and over this the sea pours and rushes with the incoming tide, into a rather deep pool (which has probably been hollowed out by this force). It lies on the lagoon side of the breccia, but within the line of curve defining the northern boundary of Motungie, Nukusavalivali and the major portion of Motuloa. Near the side of this pool and close to Nukusavalivali, in the breccia sheet, from which it has not been fully relieved, I observed one of the large mammilated corals, *Montipora* (? species) almost horizontally bedded and nearly as perfect as when it grew; being markedly distinct, in this respect, from the ordinary included masses of broken and worn coral rubble and reef fragments. A few paces to the north of this occurs a coarse sandstone dipping north 10° east, at 10°, and undergoing erosion; the strike of this sandstone would conform to the local curve of the atoll rim as is the case with the sandstones at Avalau. The existence of these sandstones indicates that conditions were once favourable for their deposition: such as (1) the former presence of an extension along the reef of the land now occupying positions on these rocks, and (2) a lagoon boundary of a form suitable for them to abut on, and agreeing with their observed present strike.

The pool close by this has, I think, received its general form before the present breach occurred, and was probably in part at least filled again when the sandstones were laid down. These have all been excavated again by the inrush of waters, which would also have removed the strip of sandstone referred to, but that it has almost certainly been protected since the time of its deposition, till within no very distant time, by the overlying material similar to that composing the upper portion of the adjacent island. Then this super-imposed material was removed by the erosion proceeding along the east side similar to that which now brings down the trees of Nukusavalivali. At that time probably much of the erosion of breccia on the lagoon side of this and succeeding islands took place. The breccia has subsequently been covered over by the advance of the island material lagoonwards, as is shown by the observed northward extension of Nukusavalivali.

MOTULOA, MOTUSANAPA AND TELELE.

Leaving the island of Nukusavalivali, we at once commence the islands which have an easterly aspect. Their general appearance changes on this side. Though their foundations and materials are somewhat similar to those of the western side, the shape of the islands themselves, as also the contour and arrangements of the material forming them, have their own characteristics, and are sharply distinct from those on the western side. The most southerly of these islands is Motuloa, and this, with Motusanapa and Telele, forms a long stretch of about 1½ miles of the narrow and regular land often found on islets presenting their side to the S.E. trade-winds, with their resulting currents. This extends from the beach east of Nukusavalivali to the S.E. corner of the atoll. Though for some purposes Motuloa and the other two islands (Plate 5) may be considered as a whole in matters that are common to each, any circumstances peculiar to one of them will be best considered under its own name.

We will take first what is common to each. The land comprising these three islands is one of the most uniform and straight insular stretches of almost constant width to be found on the atoll. The material of which it is composed on its lagoon side is characteristic of most of its length, as is that also on the ocean side for more than its western half. It is also fairly well covered with fruitful cocoanut trees, between which ferns, creepers and shrubs thrive, particularly on the western portion of its surface where small areas of incipient solution exist. This is often the case on the eastern islands near the boundary between stretches of foraminiferal sand and fine and coarse coral and breccia rubble. Outside the solution areas the roots of the trees become intertwined and matted together with the finer material and pumice; while outside the island on the eroded breccia near the platform, where their roots are bathed with every tide, "Ngie" (*Pemphis acidula*) trees thrive in several parts on the ocean side of the western half. For almost the entire length on the lagoon side, except at the east end, these "Ngie" trees, with another and larger species, occupy the sloping projections of half-eroded breccia which form the peculiar crenulated outline noticeable at this end of the atoll. Here the nearly eroded breccia reposes on the very wide lagoon platform and forms headlands and bays, both being submerged at high tide, all along this margin of these islands. Viewed from the lagoon side the surfaces of these islands appear quite horizontal, and this is made more conspicuous by the matted roots in many places projecting slightly above the looser material below. The latter is sometimes supported by a small rubble bank resting against it, and at others the finer material of which this side of the island above the breccia sheet consists, is exposed in a low undermined cliff about 2 feet 6 inches to 3 feet above high water. Generally a very small storm bank of a foot or so in height surmounts the shelf of matted roots which contains, in common with the general surface of these three islands, the drifted pumice pebbles now buried underneath it, so that it must have been thrown up since the arrival of the pumice. It also shows that the lagoon side of the island has been eroded and has consequently retreated since that time, and that this process still continues.

The lagoon platform is of great width, often near a quarter of a mile all along these three islands. On slightly excavating at several places, *Heliopora cærulea* was found, and appeared to form this platform, probably with *Porites*. Some areas of it are hidden by sand, and others by extensive thin sheets up to 30 yards in diameter of a large bivalve, *Chama imbricata*, similar to those on the *Heliopora cærulea* platforms near our landing place on the main island, where the large patches of this lamellibranch completely hide the *Heliopora cærulea*; so that only at places either where it has not been present or has since been removed, can the nature of the underlying rock be ascertained. On this platform also a very fine matted moss-like alga is remarkably abundant, forming wide areas in which occur numerous small bivalves (*Cardium fragum*). This species is so abundant in the sand beaches along these three islands as to give one at first sight the impression that it constitutes fully half of their material; the bulk of that, however, consists of *Tinoporus baculatus*.

The conspicuous feature of the ocean platform is the general uniformity of its width and its straightness

between the extreme ends of the islands. In width it is comparable to that of the ocean platform from the breccia sheet to its extreme ocean margin on the majority of those islands with an eastern aspect. In like manner between these limits its water-channels and general reef characters are similar. The corrosion zone corresponds with that of a normal corrosion zone until the east end of Telele is approached (p. 102).

These three islands, like those which we have just seen on the S.W. portion of the atoll, and more clearly like the other eastern islands, rest on a portion of the sheet on both the ocean and lagoon sides. On the lagoon side we have just seen its eroded thinned-out edges in the so-called "headlands" rising up to more or less near high-water level, sometimes over, though occasionally much less. This breccia sheet again rests on the *Heliopora* platform (O.L.1).

MOTULOA.

At this island, after the corrosion zone, we find a slope more or less steep, extending from 10 to 50 feet, in which the rise of the incline may vary from 1 up to 4 feet, and, where the incline is not great, cliffs occur reaching to the top of the breccia sheet, forming a series of buttresses, which are here also, as at other eastern islands, about 1 foot to 1 foot 6 inches above high water. The top of this cliff is then generally clear of hurricane-borne material for a short distance, varying from a foot to a few yards, after which the Hurricane Bank begins. This, along Motuloa, is nowhere very high, but in a few places it is from 5 to 6 feet above high water, though this is not more than 2 or 3 feet above the general surface of the island. The name signifies Long Island (Motu, island—Loa, long.)

Near the western commencement of Motuloa, and adjoining the wide breach, the breccia sheet has, like that in the breach, been eroded much farther back than the general outer line of the mass along the ocean side to near Motusanapa. Thus the island also has been eroded back for a considerable distance at and near the S.W. point, the trees and shrubs being undermined and falling on the breccia platform. Here the Hurricane Bank has altogether disappeared with its foundation. The breccia sheet also has in a few places been eroded back to much nearer the Hurricane Bank than at others, thus greatly reducing the defence, and forming a more or less concave outline. Here the sea has made a course for itself across the island; at first only the high storm waves found a track among the trees, but this became more and more worn till a channel was formed. These breaches occur in all stages of development, and in nearly all directions; some cut straight through the island, another appears to have met with some obstruction in its direct course, or has found an easier track, and has taken an oblique direction; while, near its eastern end, some obstruction (here, apparently, the trees) has prevented the formation of a sufficient direct outlet, and the stream has forced an additional one for itself along the centre of the island, which here is composed of the finer fragmental material to a lower depth than usual. The breach then takes a curve out into the lagoon through the nearest of the breaches at Motusanapa; along this course the bank of sand and small shells is being eroded, and shrubs are falling.

On examining these channels the breccia was seen to have been eroded or dissolved in some places below the original level of the sheet, and to have been subsequently levelled up with the general material of which the ocean side of the island was then composed. That contains no pumice, none of which was observed at the lower levels of the island mass. This was, I think, beyond doubt in these places caused by erosion from the lagoon side before the present material covered it (see Section I, Motuloa (Plate 5) as an example, and possibly also Section III). I am of opinion, however, that solution, which is still proceeding, though in a comparatively small way, in portions of this island, has, at an earlier period in its history, had also more or less to do with this; since, apart from Hurricane Banks, accumulation is proceeding only at two sand banks on the lagoon side of the island, one near and at each end; in all other places it is undoubtedly being eroded.

MOTUSANAPA.

This consists of a number of isolated portions of land, identical in character with that of the island on either side of it, so far as it has not been disturbed by the several channels. The waters flowing through these channels are eroding a course for themselves through the island mass; in this way they have, with attacks from the sea in specially rough weather, so cut up and separated the original land, that now there is not one, but many, islets at high water. On these but little vegetation now exists, except "Ngie" (*Pemphis acidula*) trees and a few other shrubs and bushes, while, at the ebb and flow of the tides, the waters stream over the corrosion zone, and along by the masses of the breccia sheet which still remain and form the defence to the tiny islets behind them. To these masses of breccia, some of which are unusually high, we may attribute the existence of these isolated remnants of land, which at no very distant date formed simply the central portion of that which was continuous from the west end of Motuloa to the east end of Telele, uniting them in one island, which then justified the title of Long Island. Relatively to other islands near by, Motuloa itself is by no means a long island, for it is much shorter than Telele, and not half as long as Funafala, but, if this union were complete, it would be the longest of the three. So I consider Motuloa to have been the name originally given to the whole island, the other two being either used to designate portions of its length (as is customary with the islanders), or later in date than their separation. In either case, if this island were named by the natives on their first becoming acquainted with its peculiarity (which I think probable), its separation must be more modern than the first ancestor of the present inhabitants. Near the corrosion zone there are big bosses of the breccia sheet more or less united with it, sometimes rugged, and almost or quite vertical, or even, in parts of it, overhanging; at others, more rarely, sloping away into the main breccia mass. This latter condition is particularly noticeable in the largest of these masses, which, indeed, is the largest and highest on any of the islands, being 20 feet × 12 feet × 10 feet above high water, and exhibiting above the breccia sheet a decided though rude stratification of its included broken and worn pieces of coral rubble, intermingled in its upper parts with more and more coral in the position of growth. This becomes more distinct (while stratification is lost) as its summit is approached. Many of the forms, being quite delicate, are broken, and the interspaces filled in with fine and coarse coral *débris*, shells, sand, &c. The base of this mass is continuous with the breccia sheet; its landward side, when near the level of the general surface of the latter, slopes away to it without any distinct line or unconformability between the two. Crossing to the lagoon side a perceptible depression in the platform is noticed inside the breccia now undergoing active erosion, which is continued on to the lagoon platform for a considerable distance; it is comparable in kind, but less in depth, with the pool or hole in which corals are growing close by the west end of Motuloa and east side of Nukusavalivali.

TELELE.

Telele (Plate 5) is called from "te," the, "lele," the native name of *Cardium fragum*. The shells of this mollusc occur in unusual numbers along the lagoon side of this island as at Motuloa; nowhere else on this atoll except at the S.E. end of Funafala are they at all conspicuously numerous among the sands and shells of the beach, while here it is often white with them. On nearing the sand bank at the N.E. end they become proportionately less numerous, the sand composed of *Tinoporus baculatus* accumulating here and extending over the area of the island in this part on to the lagoon platform. This island on its lagoon side and in the centre, starting from Motusanapa, is similar in character to the adjacent islands for nearly two-thirds of its length, when it widens out considerably, and at its eastern end resembles in outline the bottom of a high-heeled boot, the toe directed to the lagoon, the instep being represented by the accumulated sand bank. It will be noticed that there are no headlands or bays

visible where the sand bank is found, this apparently overlying the breccia. At the commencement of the arch of the boot-like form is an outcrop of soft sandstone formed of similar material to that now lying on the beach. It is being eroded, and its fragments assist in increasing the similarity between the sandstone and beach, even if they do not cause it. Another similar outcrop is observed immediately lagoonwards of the Hurricane Bank, just in front of the heel. Both these outcrops will be further discussed in describing the next island of Tefota.

The eastern end extends in a level floor back to near the Hurricane Bank, where in places a normal clinker field occurs. This diminishes in width as the island narrows, but, with an occasional small solution area, it continues more or less for nearly the whole length of the island back to its western end. On the ocean side the extreme western end, like that of Motuloa, has lost its Hurricane Bank, and is being eroded away, both these being adjacent to a wide breach. It is at this point sheltered behind the largest mass of coral breccia which is some yards distant. Between the two the breccia sheet is almost bare and undergoing slow erosion, the waters impinging on this mass being thrown high in the air and driven by the S.E. winds on to the breccia behind it. Also on either side of it the seas, divided by this mass into more confined areas on the west and on the east sides, roll on the former through the nearest breach at Motusanapa, and on the latter on to the island and in an oblique and circuitous channel, finally draining over into the lagoon. The corrosion zone also narrows quickly from this point and curves inwards towards the lagoon. The Hurricane Bank, which commences immediately east of the oblique breach, rapidly increases in height, till it is 13 feet above high water opposite the next high boss of breccia, and within another 100 yards it attains a height for a short distance of 16 feet above high water. (See Plate 5, Section 2, Telele.) This height, which is not reached anywhere else on the atoll, would appear to be due to the coral *débris* having been cast up into a mass of scrub, lining the older and less high summit, which has retained this small material; it certainly does occur in among the living and dead stems of such a scrub. Landwards is a steep declivity to a narrow incipient corrosion area at its foot, while on the outer slope of the Hurricane Bank, which is very steep just here, well-rolled pebbles make up most of its bulk. Below it there is the smooth worn breccia sheet, which becomes more rough as it approaches the corrosion zone, and then the O.L.1 platform, which is of similar width to that at Motuloa.

Continuing along this zone eastwards, other large masses, but of less height and size than at the west end of Telele, are met with on or near the corrosion area and outwards from the present breccia defence, which has been eroded back a considerable distance further than usual along this reef. The corrosion area is widened to just this extra distance, while the intensity of the wave-action over this area is apparent in the jagged corrosion hollows, many of which along here are the deepest and widest on the atoll. The water appears to always lie in some of them 1 foot to 18 inches in depth, and below the surface of the platform itself, while they are both wide and long. On the beach behind them, for a corresponding distance near this east end, lie the breccia masses torn from this area; they are found in sheets or cakes up to and over a yard square, by 9 to 18 inches in thickness. That they have come from these areas is indisputable; here are the comparatively freshly-broken rough straightish edges of the breccia sheet, agreeing thoroughly in thickness and freshness of fracture with those on the beach. On their under side they exhibit fragments of *Heliopora* among other corals, similar to what one has seen on such masses at other islands. Many similar masses lie where they have been simply lifted and fractured but not removed; others are turned over, others moved part of the way and lodged against a fixed unmoved mass or other obstacle, while all up the Hurricane Bank they lie more or less closely and thickly. This certainly is the most severely torn up breccia sheet I have seen, though there are other places on these eastern islands where it has been similarly though less intensely affected. Approaching the "heel" of the "boot-form" of this end, the rugged character of the breccia sheet increases and widens, but the corrosion hollows terminate a short distance before reaching the breaches which separate Telele and Tefota. Along the "heel" the eroded breccia passes till it reaches a curve

continuous with the lagoon edge of most of the "headlands" of breccia on the lagoon side. Just where the breccia ceases is a large block of *Porites*, apparently *in situ*, protruding through it.

Regarding these three islands as a whole, we have seen in them a breccia defence all along the ocean side, but broken in places; there a breach is forming or has formed through which the S.E. gales sweep over a portion of the island to the lagoon, carrying away the fragmental material of which it is largely composed, undermining the trees, creating channels or enlarging any already made, and eroding deep into the breccia sheet, so that these channels once made become enlarged more and more. On its east end severe corrosion is taking place, removing the breccia sheet and corroding deeply into the floor of the reef itself. Thus denudation, solution, corrosion and violent erosion are combining to remove, on almost every hand, the material of the surface and every side of these three islands, except at the few relatively small areas indicated, where sand is accumulating and may for long so continue to do, until it may possibly form the nucleus of a sand island farther out on the lagoon platform, when these older present islands have been all removed except perhaps a thin mantle of the breccia sheet.

Indeed, though to understand the history and destiny of the islands on this atoll every available piece of evidence obtainable is necessary, and even more would have been welcomed, yet these southern reefs and islands appeared to me to supply the index or key to most of the islets on the atoll, especially since they exhibit some of the more intense phases of erosion and the manner in which it operates in nearly all its stages.

TEFOTA.

Tefota (Plate 5) is a tiny islet situated on the south-east corner of the atoll. Its importance arises not from its size, but its position and relation to the larger land on either side. Its elevation is but about 3 feet 6 inches above high water; its surface is composed of foraminiferal sand mingled with a little rubble and beach *débris* like that on the islands on either side of it. There is but little Hurricane Bank and that chiefly on its west side. There are no breccia buttresses or low cliffs to defend it from the encroachments of the waves. It rests upon the breccia sheet, which slopes away steeply to the canoe channel in the breach on the east side, and but gradually to the breach or channel on the west, and to the sea on the south, in which direction it is very rough and jagged.

This island though so small and exposed would appear to be fairly stable and to have retained its surface material. It has probably continued as a remnant of the land which at one time formed a single island. It must have remained as now for a very long time, for besides several cocoanut trees less than the usual height it has two quite tall ones. The erosion in the breach on the east side has been considerable; the canoe channel in it can be used till about half tide, and consequently admits of the passage of a large stream of water at ebb and flow. The west breach is shallower and is only covered as high water is approached. The fact that so large a surface of the breccia sheet on the platform and in the breaches at this corner is partly removed, affords a good opportunity to observe its composition and general features. It is composed of usually angular and flattish coral rubble lying at all angles, but generally conforming approximately to the horizontal, and I fancied inclined more to the sea than otherwise, the interstices being occupied by smaller fragments of coral and some sand. On the underside of some of the recently overturned large flat sheets or cakes of breccia near this island, smaller sized and less worn and fractured parts of coral were commonly found, many of which were observed to be *Heliopora*.

Among this breccia was one very large and a few smaller corals of the strong form of *Montipora* species, apparently embedded in the breccia as it grew, having been but very slightly injured by contact with the drift coral of the breccia sheet, which appears to have grown during the deposition of that sheet, then to have been covered over by it, and at last to have been again exposed by the recent removal of its upper part. I had occasionally seen coral in a similar position which struck me as being

in situ, but that seen at Nukusavalivali and the much larger specimen here make this still more evident. A few *Porites* are seen above the worn or eroded breccia sheet. This sheet has apparently been continuous from Telele to Funafara, as it still is at the similar easternmost corner of Fongafale (the principal village on Funafuti), each of which angles have many striking resemblances to each other.*

Here the breccia sheet has been broken through; there it has become very narrow and will probably be also breached at no very distant date. At Fongafale, again, a soft sandstone covers a considerable area inside the Hurricane Bank at the swamp; at Tefota there are several beds of soft sandstone in a curve, so that the parts now remaining on the west breach form portions of a basin of sandstone dipping from every side to its centre, lying inside the remains of the breccia sheet and now being more or less eroded. There is also a small outcrop of incipient sandstone on the east side of this channel not far from the entrance to the tiny bay there, also dipping to the passage and being eroded. The two sand points on either of the inner ends of this shallow passage are extending lagoonwards, but the east side is undoubtedly being eroded, as is proved by the low undermined cliff without a storm bank of any kind whatever; with the cocoanut trees falling and the matted roots projecting as they grew before the breach occurred. This has been a portion of land very similar—apart from its size—to that at the main village, and is now being slowly removed by erosion, accelerated by the breach or passages here.

As the lagoon near this islet of Tefota is very narrow, it has silted up much more rapidly here than at the main island. There a swamp exists inside the Hurricane Bank; here there is little doubt that the inner part of this wide breach and the site of the soft sandstones and present tiny bay to the north were not very long ago so occupied, and the present swamp extending from the tiny bay along the inside of the Hurricane Bank is but a northward extension of this swamp to the island of Funafara.

Bounding the northern side of the breach eastwards of Tefota there is a Hurricane Bank which looks much like a deflection of that which bounds the ocean side of Funafara, once continuing across the breach to Tefota but now driven back, like a gate pushed open. There can I think be no doubt but that this is practically what has happened; first a breach has been formed through the old Hurricane Bank, then erosion of the breccia has followed, and some of this removed material has been driven in and piled up to a small extent along this side of the channel which, as it widened, rolled back the Hurricane Bank, adding more to it and increasing its height and bulk up to the present time.

FUNAFARA.

This island (Plate 5) is now the largest on this end of the atoll and the second largest of all. It is formed at its southern end by a wide area of flat sandy land which continues to the northern end, though of reduced width and with an admixture in varying proportions of coral fragments. Near the south end of this island is the site of the village of Funafara, next in importance to Fongafele.

At the widest portion of its south end the breccia sheet does not extend through to the lagoon side, being undoubtedly masked by the sand accumulation there, which near the point is unmistakable. As the island narrows, the eroded breccia is exposed in places, and sometimes forms the crenulated outline, as it does northwards of the village where, for about one-third of the length of the island, it extends in a series of thin sloping tongue-like projections similar to those on Telele, between which are sometimes a little beach sand and *débris*. North of this the breccia maintains a moderately even line till towards the end, when it is observed to be overlain by the newer breccia.

* Thus at both, the lagoon platform is very wide—uncommonly so; at both, the breccia sheet has extended quite round the corner; at both, silting up has taken place in the lagoon, while extensive sand accumulations have greatly extended the island lagoonwards.

interest. The thin sheet of the newer breccia covering the partially eroded surface of the breccia sheet in some places on the lagoon side which was noted near the northern end of Funafara, is also present on the same side of this island.

LUAMOTU.

The breach between Mafola and Luamotu (Plate 6) is much wider than that between the former and Funafara. At two points this is being eroded to a greater depth than at the other parts, forming channels. Corrosion occurs a little before Luamotu is reached and continues for some distance along its ocean side. A decided variation in the width of the outer platform may be observed along this island, otherwise it is in some respects similar in its outer zones to that at Funafara; though the corrosion zone is wider, and very irregular and rugged. At the Hurricane Bank a peculiar crenulated outline occurs simulating somewhat the "headland and bay" outline in the breccia and at the southern part of Funafara, with the difference that this occurs in the Hurricane Bank above the breccia sheet, while that is in the breccia sheet itself. No doubt this is caused by the greater or lesser obstructions to the wave action offered by the breccia, but it indicates that the waves are gaining more and more on the island mass, which will in time result in another breach, thus probably creating another tiny islet; this increase in number of islets through dissection of larger islets, being a prelude to their complete removal.

The clinker field at this island is often very slightly developed and sometimes scarcely distinguishable from lagoon-formed *débris*, though at other places it is of normal character and even quite rugged. There is quite a noticeable Hurricane Bank or storm bank along parts of the lagoon side of the island, which considering the narrow limits of the lagoon is remarkable. More remarkable, however, is the extended line of almost level straight breccia sheet, forming a cliff, for nearly the whole length of this island, as well as a bare upper surface from which the island material has been removed for some 30 yards wide for a similar length.

This island is nearly the same distance from the western reef (over which the waters roll in rough weather) as those on either side of it. Its chief difference consists in its direction, which is at right angles to, and so meets, the N.W. monsoons. The waves at high tide leap the western reefs, and are driven through with reduced force on to the broadside of this island, while they roll somewhat obliquely along those on either side of it. Hence they are not in the latter case so destructive as at the island of Luamotu. At only a very few spots does the lagoon side of any of the islands lie at the same angle of direction; but at each place erosion is unusually active for the lagoon side.

MATEIKA.

The breach between this (Plate 6) and Luamotu is marked by a more advanced stage of erosion than those of the two last. At two places the channels are being eroded deeper than usual, the most northern of these being also much deeper; it is at its deepest part not much above low water; this occurs, it should be noted, at the angle of the convexity of outline on the lagoon side caused by the difference in direction of the two islands. On the ocean side of Mateika the rugged nature of the corrosion zone of the last island is in parts repeated. One or two very large blocks of coral breccia, apparently *in situ*, occur in this zone. On the outer edge of this platform, and to some extent that of the last island, the living *Lithothamnion* zone (O.L.10) is much higher than usual, forming quite a lake between it and the corrosion zone, with the living *Lithothamnion* zone (O.L.10) still well elevated above the surface of the water so enclosed. The Hurricane Bank on this island in some parts attains a greater height than at the last island, being 8 feet above high water, while on the lagoon side also it sometimes approaches near to that height. The southern part of the lagoon beach is strewn with breccia and old coral blocks up to 18 inches in diameter, while about midway along it numerous larger blocks of breccia from the sheet

of that material occur, causing the platform near the breccia and the beach to resemble closely in general character and appearance some of the less rough of the ocean beaches.

The middle portion of the island, however, is convex in outline on this side; here erosion has been much less severe, and so the island is correspondingly wider, the Hurricane Bank scarcely exists, and what there is, is more sandy. As the northern end of the island is approached, the erosion has again been active, the Hurricane Bank reappears though less in height, and the beach is formed of pebbles, which are swept up and down it, with great force even in moderate weather, by the back-wash caused by the adjacent channel which separates this island from that of Falefatu. By that action this end of the lagoon side of the island has been worn back, so that it has become very narrow. Near it a very large block, 8 feet by 7 feet by 4 feet, of single coral of the species allied to *Goniastræa favistella* occurs *in situ* projecting through the beach above high water. This is the first deep or wide passage that we have passed in our journey round the islets since that of Fuagea on the western reef of the atoll.

FALEFATU.

This island (Plate 7) occupies a unique position on this atoll, situated as it is between two of the chief passages—that of Mateika and Te Bua-Bua (the former being the widest of any on the atoll, *i.e.*, 1¼ miles)—both of which are sufficiently deep to give safe passage to ships entering the lagoon, and are the two greatest passages for the waters of the lagoon to enter and escape with every rise and fall of the tides. The shape of its breccia sheet, though a considerable distance back from the edge of the reef, yet strikingly conforms to it. It would appear to be also regulated largely by the direction of the chief winds and currents. This island is one of a few where the effect of their force in first forming, and then removing, under changed conditions, the breccia sheet as well as the island upon it, may be best studied. The maps will show that the distance of the breccia sheet from the outer edge is increased wherever it crosses the direct line of the general direction of the winds and currents, and is diminished wherever this strikes the outline of the island in an oblique direction. The existence of the island itself in this position is probably due to a considerable projection oceanwards of the 4 and 100 fathom lines of submarine reef, which presents at this place a keel-like outline the result of which, as the waters strike and divide on it and so lose some of their force, is a great width of reef rim or platform.

Similar submarine projections oceanwards would appear to favour the development and continuance of islands in the areas sheltered behind such projections, inasmuch as at each position where these conditions obtain, even though they may appear to be the most exposed, there are yet found considerable widths of upper reef rim and islets, as at Fuafatu, Tefota, Falefatu and even at Fongafale. I may add that in this position there is little doubt that this island would not have remained till now, but for the submarine projection, which favours the formation of breaches and passages.

Falefatu consists of a sheet of breccia of very irregular outline lying on a base of tidal reef or platform, which appears nearly all around the island. It is in a more or less eroded condition, except at the central portion of the concave lagoon side, where pebbles and foraminiferal sand have accumulated and now obscure the breccia sheet for about half the length of this side. Here there is a considerable forward wash which throws up the sand and shingle in a steep bank, while the roar caused by the rushing forward and backward of the pebbles of coral and coral breccia, especially near the northern end where the island is narrow, was so great at three-quarter tide, with but a moderate breeze, that one could scarcely hear one's own voice. Extensive erosion has taken place on the ocean side as indicated by the remnants of breccia still existing on the tidal platform. This has been so far invaded that the island near its centre is almost severed, there being but a few paces connecting the north and south ends together. Very little Hurricane Bank or coarse material exists anywhere as the southern end is approached.

This, the widest portion of the island, is composed chiefly of sand and finer material; no approach

to a solution area was observable. On the northern half, however, the island is composed almost exclusively of breccia and rubble from it formed into Hurricane Banks; that on the ocean side rises precipitously to the height of 7 feet above high water, and terminates in a sharp peak-like ridge, while the descent to the centre of the usual position of the clinker field is much more steep than usual. Then, rising to a less height towards the lagoon, this also consists of rubble, though of somewhat less size than on the other side of the central depression or solution area, which is discontinuous at this end for about one-third of the island's length. At the northern end the eroded breccia extends for a considerable distance beyond the point of land above high water, diminishing in thickness the greater the distance from the present end of the island till it almost blends with the tidal platform. Near the point of the island, removal of breccia above high water has been comparatively recent and the island has been to that extent shortened; a continuance of this shortening seems imminent, as the breccia is being more and more eroded and removed, while the rubble, *i.e.*, the Hurricane Bank upon it, is being removed slightly in advance of the breccia.

The conspicuous features in the history of this island would appear to be :—

1st. The general erosion of the breccia at its S.E. corner, and the strong "bay and point" like outline formed by it.

2nd. The extension of the southern end towards the lagoon.

3rd. The concave outline of the lagoon side caused by the extension lagoonwards last named, and also the facilities which the outline offers for the reception and retention of sand and shingle accumulations.

4th. The probable speedy division of the island into two.

5th. The retreat of the northern end of the island.

Thus erosion and corrosion are proceeding around the island for about two-thirds of the distance of its outline, and accumulation of sand and shingle for the remaining one-third, some of which is on the S.E. corner of the island, where sand forms the point and also the greatest part of the beach, but the chief part of the accumulation is on the concave lagoon side.

The development of this island has been similar to those already described, while it appears probable that dissolution of the breccia sheet will continue, though more or less slowly in proportion to its distance from the outer edge of the reef, the presence or otherwise of projecting breccia not yet removed, the form of the submarine contour, the angle at which the chief winds and currents cause the waves to strike the island's outline, the strength of the force with which they strike, and similar modifying influences. When this is gone or nearly so, the finer loose material of the island will not long survive strong attacks.

FUNAMANU.

Funamanu (Plate 7) is separated from Falefatu by the Bua-Bua passage, which is 1 mile wide and that most frequented by trading vessels. It is situated near the southern end of the reef on which further north stands the main island, and here commences the longest stretch of reef, awash at low tide, on this atoll, as it is continuous for over 16 miles. On the long point of reef beyond the end of the island, numerous pieces of breccia and coral rubble are strewn about, while the corroded remains of the breccia sheet cover the tidal platform for many yards before the end of the island is reached. Within a few yards of this stands the large dome-shaped white beacon. This island conforms closely to the shape of the tidal platform upon which it stands, except at its northern end where its point recedes from the outer reef edge considerably. The base of the island resting on the tidal platform consists first of the breccia sheet which can be observed all along the beach on the ocean side, and for some distance at each end of the island on the lagoon side, while it can also be traced along the lagoon beach. There are *in situ* on the southern half of the lagoon platform two large upstanding bosses of the coral *Porites* covered by about 2 feet of water at high tides, while on its northern portion a small stunted living specimen of *Heliopora*,

8 inches by 7 inches by 6 inches, was obtained in a shallow pool which allowed sufficient water to cover it at low tide. The central part of the lagoon beach is occupied in part by recent gravel and shingle from the breccia with fragments of coral. The Hurricane Banks surmount the breccia sheet, and for most of its length incline sharply from it to a central depressed area in which are small spaces where solution is taking place. The general surface of the middle of the island is composed of fragments of breccia and coral with but little sand, though large masses of coral breccia exist in parts of its southern half which is undergoing solution. These occur as rugged masses, between which pits and caverns are formed and forming; they afford a suitable home for the large Puka-Vai trees (*Calophyllum inophyllum*) growing here. These trees give shelter to large numbers of birds, as do the Fetau trees at Amatuku.

On the ocean beach occur several outliers of breccia, often well out from the Hurricane Bank and above the general surface of the breccia sheet, some containing in their upper parts small corals in the position of growth filled in with smaller fragments cementing all together. Their lower parts often exhibit worn blocks of coarse coral with a suggestion of almost horizontal stratification. These breccia masses are really the most oceanward part of the breccia sheet, which extends to and across the island, but is now corroded and worn by the waves till only the low pinnacles and these larger isolated masses remain to mark the original boundary. Behind these outposts at the Hurricane Bank the breccia sheet is nearly obscured by the drifted *débris* forming the bank, but it still continues far into and at both ends at least quite across the island. Near the southern end, on the lagoon side, occur beds of a finer breccia with a distinct dip, north 40° east, at 10° reposing on the platform (O.L.1). The southern end of the ocean platform is of a rusty brown hue from the presence of an alga which covers almost everything from near low water almost up to the beach line.

FUNANGONGA.

The platform between the last island and this (Plate 8) is much constricted, but widens again as it approaches. Though subject to some variation it maintains on the whole about the average width on the ocean side of the island, and is fairly regular on the lagoon side. A striking feature of the rough zone on the ocean side is the very irregular outline of the breccia sheet, which like the southern part of Funafara presents a rampart-like outline with projecting buttresses and short sloping beaches between them, appearing at high tide as a headland and bay outline. These headlands or buttresses are sometimes continuous with the breccia sheet behind them and under the Hurricane Bank on into the island. This breccia sheet is also seen at each end of the island to extend quite across and on to the lagoon platform where it forms the base of the island for some distance, itself resting on the platform O.L.1. Over the corroded zone, which is also a portion of the same breccia sheet, the waves sweep at half tide and onwards, rushing up between the buttresses and carrying quantities of coral and breccia fragments, which thus become worn and rounded. Here the bulk of this beach *debris* consisted of fragments up to 8 inches long, of two species of coral, both of which retained the bright fresh colours and bloom-like surface common to them during, and for a comparatively short period after life. This shows them to be in a living and flourishing condition, near by and almost certainly, therefore, on the ocean reef beyond. They are *Heliopora* and the yellow *Millepora*. The fragments of the former included robust specimens, many of which were gathered and some brought away; the blue of the *Heliopora* and the bright yellow of the *Millepora* were striking for their clearness.

The erosion caused by the attrition of this material has smoothed the breccia in places and is wearing away the inner sides of the buttresses, some of which are quite severed from the main breccia sheet and stand alone as outliers. When they are higher, as is sometimes the case, they appear at first in their isolated position to have no connection with the main mass, but here, as at a few other places, their relationship is in part disclosed. On the upper portion of some of them corals are seen in the position of growth, with the spaces between them filled in with coral fragments and *débris* and all cemented together.

A third and last stage of these big coral masses is to be seen in some cases where the undermining by borers has continued until the base has become so small that it is too weak to support the superincumbent mass. They have, therefore, been broken off from their base by heavy seas, and are now to be found as large free masses in various positions on the beach or some way up the Hurricane Bank. It has not often happened that one has observed unequivocal evidences of the existence of the newer breccia L.2.B. on the ocean side, but here for a short distance along the low breccia cliff on that side it does occur, containing blocks of the older breccia cemented together in the mass, and lying unconformably on the O.2.E. It is now, however, being eroded, and worn back to the general cliff-line in common with the older or main breccia sheet.

Several cocoanut and pandanus trees are lying down the ocean slope of the Hurricane Bank, the drifting back of this farther on to the island having removed the material surrounding their roots. On its inner side a wide area is occupied as a clinker field, made up in some parts of larger and smaller coral blocks, while in parts deep pits and caverns occur between jagged and clinkery coral and breccia, where solution is often found to be in active progress. The width of Funangonga is considerably more than of any other island on the southern part of the atoll.

On the lagoon side between the breccia of either end the beach is made up of foraminiferal sand, chiefly *Tinoporus baculatus*, with a small admixture of the usual beach *débris* (L.9.B.) rising to the vegetation line or a little beyond, and then gently sloping to near the centre or to where it meets the solution areas or the coarser material. Nearing the centre of the island is similar material, but older and covered by vegetation, the height of which indicates the inner part to be the older, while more coral fragments appear on the surface as the clinker field is approached.

FATATO.

This island (Plate 8), like the last, is joined at either end to the next one by a long narrow strip of reef which does not equal the normal width of the ocean platform outside the pinnacles together with even a very narrow lagoon platform. Thus, probably, it has never been, except near each island, the site of a breccia sheet or the usual island, but has remained from the first as a reef not much above low water, with little more than loose blocks and *débris* upon it. The width and character respectively of both the ocean and lagoon platforms are remarkably constant around Fatato. The usual pinnacles and rough zone extend in a line distant some 30 yards outwards from the low cliffs. Within this is the rough zone (O.2.B.), then the worn or smooth zone (O.2.C.), and then O.2.D. or low cliffs of the breccia sheet. In this O.2.D., near the southern end, patches of L.2.B. or breccia more recent than the usual breccia sheet occur as at Funangonga, and like it enclosing masses of the older breccia inclining at an angle of about 20° towards the platform. The differences in dip between it and the older breccia sheet, together with its encircling slabs of the older breccia, assist one in readily recognising its presence. It is here also undergoing erosion, and no deposit now forming in this position corresponds to it, for it more closely resembles the material constituting the Hurricane Bank on the top of the breccia sheet, excepting that a conglomerate sometimes underlies this newer breccia (L.2.B.).* There are several big and high blocks of breccia along this Hurricane Bank, while some of those that appear to be *in situ* and still united to the breccia sheet are very high and correspond in elevation to some of the high breccia masses that usually appear as outliers, showing the relationship of these and all outliers. The Hurricane Bank is here in places unusually high, but as it slopes inwards to the centre of the island, it is seen to be composed of smaller and much less rugged material than that of the clinker field of the two islands south of this, and solution pits were rarely seen.

Fatato on its lagoon side closely simulates Funangonga, as at either end the breccia sheet passes across

* The symbol L.2.B. indicates it to be a lagoon production, but while probably agreeing with the age of the lagoon-formed breccia, this has, no doubt, been formed on the ocean side.

from side to side and continues for comparable distances along each island, the southern end exposing in both cases much the longest stretch of breccia, while the space between these breccia outcrops is similarly occupied by foraminiferal sand and *débris* which also extends inland to the clinker field, alternating with this near the junction of the two. Large pebbles up to 18 inches in length occur, however, on the lagoon Hurricane Bank resting on the worn breccia sheet, while on the northern end is an abnormal accumulation of foraminiferal sand, chiefly formed of *Tinoporus baculatus*, reaching the height, unusual on this atoll for a sand accumulation, of 13 feet above high water, which height it maintained nearly across this narrow end of the island. This is only exceeded in the single instance of the high rubble Hurricane Bank occurring at the southern islet of Telele for a short distance.

Near this end, the older sand bank, where it is being covered by matted roots, is being undermined by wave action, so that a small vertical section, 3 feet 6 inches to 4 feet in height, is formed with the matted roots, holding together 6 to 8 inches of the surface sand and *débris* and projecting several inches beyond the almost vertical sand cliff. It does not, however, follow that the sand removed in forming this cliff is entirely lost to the island, as probably most of it is drifted back on to the sheltered wide beach again and driven higher and higher, first by water and then by wind, some of it possibly even to the highest ridge, which is well protected oceanwards from general wave action by the rubble Hurricane Bank.

APPENDIX II.

NOTES EXPLANATORY OF LETTERING (OTHER THAN THE SYMBOLS IN THE INDEX) ON THE GEOLOGICAL MAPS.

By G. SWEET, *F.G.S.*

FUAGEA (PLATE 3).

A. Several projecting bosses of upstanding rocks are seen here; all those which could be tested were found (except in the case of a few breccia pinnacles) to be *Porites*.

B. *Porites* block *in situ*, 7 feet by 4 feet 6 inches by 4 feet high; its top level with high water; lies close up to the base of the sand beach.

C. Perceptible increase of the admixture of nullipore on this side compared with the south end of the lagoon side.

D. Several cocoanut, pandanus and other trees are being undermined and falling here.

E. *Nullipore* sandstone dipping 9° E., composed of practically the same material as the present beach just here, and now undergoing erosion.

F. The material composing this island is made up chiefly of foraminiferal sand, in which *Tinoporus baculatus* predominates with small fragments of nullipores, some being *Halimeda*. The top is undulating, especially on the ocean side.

G. Very few worn coral fragments and but very little breccia.

TEFALA (PLATE 4).

A. These *Porites* bosses are apparently *in situ*.

B. This island, like Fuagea, is formed of sand and fragmental. It is essentially a sand island which has shifted lagoonwards, as shown by the dip and nature of the sandstone.

C. Sandstones cover over the breccia and *Porites*, both showing through in places.

D. *Porites* in great numbers about here, 1 foot 6 inches to 3 feet above platform, piercing the breccia. These are somewhat like those at Falaoingo but are not quite so large.

E. Small fragments of new coral abundant here.

F. No breccia or rarely any, and but few small pieces of old, but numerous pieces of new coral up to 3 inches and over.

FALAOINGO (PLATE 4).

A. But little *Heliopora* seen here in breccia.

B. Big bosses of *Porites* here *in situ* up to 3 to 4 feet above high water.

C. The water had floated a cocoanut here, which had grown 18 inches in height and 15 inches of root since I was first here (two months previously).

D. Much drifted pumice up to 8 inches by 6 inches. Few and small cocoanut trees.

E. *Porites* piercing the breccia.

F. Channel at high tide.

G. *Porites in situ*, very much bored by various old marine organisms in some blocks, now about high-water level.

H. Large bosses of *Porites in situ*, nearly close together all along here, showing reverse cone-like structures in side fractures.

TUTANGA (PLATE 4).

A. Sand and *débris* filling in between the *Porites* tops and forming a beach, which at its highest point is above them.

B. Fragmental and small rubble beach from these two points.

C. Small bank of fragmental and rubble as on outer beach, forming an almost complete loop.

D. Shallow boat passage out here.

E. Small boat channel through which the ebb tide at the time of survey was running $2\frac{1}{2}$ miles per hour.

F. Numerous large bosses of *Porites* all about here, most of which can be recognised as being *in situ*, and standing from 1 to 4 feet above high water.

G. This area is largely occupied by bosses of *Porites* 2 to 3 feet above high water, and blocks of breccia, the latter both fixed and broken; all undergoing solution and covered with mosses, while below and between them are holes, pits, and caverns, in the deepest of which water is found at high tide, and among which thrive dense masses of ferns and scrubs; while towering over all, and higher than on any other island on this corner of the atoll, are the tall cocoanut trees.

TENGASU (PLATE 4).

A. Abundant bosses of *Porites in situ* as at Tutaga.

B. *Porites* appearing through the sand of the island.

C. Bosses of *Porites* appearing through the breccia.

D. Breach through here at high tide during rough weather and westerly winds.

TEAFOAFOU (PLATE 5).

A. Very little storm beach here. The solid breccia is but thinly covered in places by rubble.

B. Occasional scanty rubble and shingle beach here.

C. No beach here.

D. Slight beach of rubble and shingle.

E. Ngie bushes along here.

F. Channel at half tide; tailing out both ways and very narrow between the two sandbanks.

G. Small shifted pieces of breccia mingled with a little foraminiferal sand form the beach on this side of the channel.

H. The surface of this end of the island is almost flat, in places freely bestrewn with pumice, which in some parts where the soil has been partially removed almost covers small areas.

J. The masses of *Porites* are much less abundant here.

K. Sandbank newly thrown up on old platform and enclosing a portion of the platform.

L. A gently-rising platform of breccia and coral bosses.

M. Ngie trees chiefly, all round this sea side of island and along the beaches; only a comparatively few good cocoanut trees. Apparently the sea sometimes sweeps over a large part of this island, so that there is rarely more than a sign of beach.

N. Much of the *Porites* here is relatively smaller and lower compared with those usually seen a little north of this, as though from arrested growth.

AVALAU (PLATE 5).

A. Tops of *Porites* appear through the surface of the breccia.

B. Only the denuded stumps of *Porites* seen about here.

C. The breccia rampart is reduced to very low cliffs or pinnacles or scarps.

D. Denuded stumps of *Porites*.

E. Somewhat soft coarse sandstone in parts, giving place to fine breccia.

F. An abrupt step of 2 feet 6 inches in breccia occurs here, which gradually disappears.

G. Native well in sandy soil intermixed with gravel and shingle somewhat similar to that round the native wells of Fongafale.

H. Very little except breccia and coral rubble, up to 12 inches by 9 inches by 6 inches.

J. *Porites* seen in a few places, especially along the beach.

K. Channel eroded in breccia.

L. Breccia composed of sharp angular blocks with a fine-grained cementing material.

MOTUNGIE AND NUKUSAVALIVALI (PLATE 5).

A. The sand along these two north beaches yields the most perfect *Tinoporus baculatus* seen anywhere in quantity on the atoll.

B. At this place there is an area of newly deposited large and small sized coral rubble, all loosely disposed, and with a general but irregular bedding, like the breccia itself, which it closely simulates; it lies under water, behind the breccia cap, and sheltered by it.

C. Cocoanut and pandanus trees falling here.

D. Coarse sandstone, ↓ 10° N.

E. *Montipora* is again seen among the breccia, right side up, almost as perfect as when it grew, but slightly weathered, imbedded in and partly covered by the eroding breccia, and apparently *in situ*.

F. Alternately fine rubble and coarse and foraminiferal sand.

G. Coarse breccia.

H. Pool with patches of growing coral.

J. Some of the breccia sheet appears to dip seawards

MOTULOA (PLATE 5).

A. Matted roots being undermined; shrubs and trees falling.

B. Projections of breccia covered with "Ngie" trees.

C. Storm breach.

D. Pumice scattered about in parts over surface, thick in places, and matted with the roots.

E. Coarse sand and gravel, only a few large stones.

F. Immense numbers of the small bivalve *Cardium fragum* here.

G. Much of this island is covered over with fragments of pumice, and, in other places, swept over by the south-east gales, which have made and are making breaches right across, wherever the breccia defence is nearly or quite eroded.

H. Breccia defence is nearly eroded here.

J. Breach through, between the trees.

K. Breccia defence eroded in places, and here breaches exist or are commencing.

L. Channel through at high water and rough weather, over breccia which is being eroded.

M. Foraminiferal sand point.

N. Breach here.

O. Some small-sized coral rubble about the top, occasionally, when in considerable quantity and deep, undergoing solution.

P. Sand on the beach covering the worn breccia below.

Q. All along these breaches erosion is in active operation.

R. No distinct beach.

S. Loose breccia blocks torn up from the breccia sheet and platform, and driven shorewards.

MOTUSANAPA (PLATE 5).

A. Several big bosses of breccia, one 7 feet above high water, with smaller broken fragments of coral on its upper part.

B. The erosion in these breaches is very marked, and actively proceeding.

TELELE (PLATE 5).

A. Big boss of breccia, 20 feet by 12 feet by 10 feet, above high water, capped by many kinds of fine and thick corals, apparently *in situ*, but with more or less weathered and broken tops, which appear to have been for a long time supported and protected by imperfectly cemented breccia filling; this support has been the first to be gradually removed by solution, and has left the finer firm corals standing, as now seen. In their lower parts these bosses show uneven bedding, approximating to the horizontal. In their upper parts no stratification is recognisable.

B. Breach commencing through here. The high breccia rampart is not yet worn down from this point eastwards.

C. Good-sized pebbles of pumice on the soil.

C[1]. Fragments of pumice are found 13 feet up the Hurricane Bank, *i.e.*, 3 feet below what is, a short distance away, the summit, this being the highest spot on the island.

D. Large boss of breccia here 9 feet above high water.

E. Very large blocks of breccia.

F. The erosion along here is most marked and severe, the longitudinal channel in the erosion zone being both deeper and wider than elsewhere observed, and the massive cakes removed from it are now to be seen at the base and up the side of the wide Hurricane Beach.

G. Much of the surface of this island is composed of similar material (shells, sand, and *débris*) as the lagoon beach adjoining.

H. Fine breccia, inclined to present channel.

J. Boss of *Porites in situ.*

K. Soft sandstone of similar material to new beach sand, ↓ 10° to basin or passage.

L. Soft sandstone of similar material to new beach sand, ↓ 10° to basin.

M. Foraminiferal sand, with a large proportion of *Cardium fragum.*

N. Patches of *Chama imbricata* are found here and there over the *Heliopora* reef, of 100 yards or more in diameter.

TEFOTA (PLATE 5).

A. Breach-channel at half tide.

A[1]. Canoe passage or channel through breccia at half tide.

B. This island has but two tall and seven smaller cocoanut trees growing on it.

C. Many shifted cakes of the breccia-capping above and on the platform floor.

D. The flattish stones that mainly compose these beaches are generally inclined to the sea, but the stones in the breccia lie at various angles, and in any direction, the majority approaching the horizontal. A large form of *Montipora* (? *sp.*) coral up to 6 feet in diameter is interbedded among the breccia as it grew. It is scarcely injured at all, and but little weathered, and is but slightly inclined to the sea. It appears to have grown during the deposition of the breccia cap, to have then been covered and protected by it, till the progress of erosion has again partially uncovered it as it is now.

D[1]. Large dead flat corals, *in situ*, among the breccia, distinctly in a better state of preservation than the main mass of the breccia.

E. *Heliopora* seen here, embedded nearly all over the under side of large overturned masses of the breccia.

F. Alternate layers of coarse and fine sandstone, dip 9° to basin, *i.e.*, approximately south.

FUNAFARA (PLATE 6).

A. A little new coral being thrown up here with portions of the eroded breccia cap lying on the platform.

B. The usual breccia blocks are thrown up here with smaller rubble.

C. The breccia rampart along here presents a very broken line, having re-entering angles and outlying rugged pinnacles at short intervals. In the spaces between the projections there is a more or less smooth floor and steep beach, with rolled fragments, the former presenting short and bold, steep, vertical, or overhanging cliff-like headlands to the ocean.

D. *Porites* block, 10 feet by 6 feet by 4 feet, on or piercing breccia.

E. Path to Funafara village.

F. Small solution area or swamp.

G. Masses of breccia, but not usually so high as at Telele.

H. Mass of *Goniastraea favistella* on or piercing the breccia cap, *in situ*. Size 7 feet by 6 feet by 6 feet 6 inches above high water.

J. New fragments of *Heliopora* seen in several places here.

K. Mass of breccia, with several small broken corals on top, cemented in the mass, apparently *in situ*.

L. Boss of *Porites*, 6 feet by 4 feet by 3 feet, above the breccia, and embedded on top of the breccia cap or piercing it, probably *in situ*.

M. Breccia showing an irregular bedding, with dip 1 in 12, at about right angles to shore line.

N. Big mass of breccia well up on beach, 12 feet by 9 feet by 6 feet, above high water, showing bedding plane 1 foot above high water, and apparently *in situ*; some small corals on top, also apparently *in situ*.

O. Boss of *Porites*, 5 feet by 5 feet by 1 foot 6 inches, above the outer platform floor.

P. Coarse angular blocks of breccia up to 3 feet in diameter, torn up from the corrosion zone, and now forming an outer rugged addition to the Hurricane Bank.

Q. The breccia on the lagoon side about this end of the island partakes of the nature of sandstone, being formed of sand, shingle, and small rubble.

R. Boss of *Porites*, 5 feet by 5 feet by 1 foot 6 inches, above lagoon platform.

S. Dead nullipore fragments about here.

T. All along here there are breccia projections, with occasional streaks of beach sand, between them and the storm, or small Hurricane Bank.

U. Headlands of breccia with bays between; streaks of sand and sub-angular coral gravel constitute the beach here.

V. No sand beach here.

W. The beach along here viewed from a short distance has a crenulated appearance at low tide, caused by the unequal erosion and solution of the breccia, which now forms headlands and bays, in shelter of both of which at their base a narrow streak of foraminiferal sand and *débris* often rests. Ngie trees grow persistently in this precarious position on the higher parts of the headlands.

X. Sand floor alternating with fixed and a little loose breccia, all covering, wherever tested, the dead *Heliopora* reef *in situ*, with the sand between and occasionally over all.

Y. Where the breccia begins at this point, a few new coral fragments occur.

Z. Sand only along here.

A^1. Very recent accumulation of worn foraminiferal sand here.

B^1. Trees undermined and falling along here, the land being probably invaded by the lagoon, or from the flow of waters driven by heavy weather and high tides through the Tefota passages. Pumice thickly matted with the roots.

C^1. This flat is composed of lagoon material, as is the flat just across the passage at Telele.

D^1. Outcrop of soft sandstone dipping to passage.

E^1. Eroded breccia floor. Recent beach of old coral and breccia fragments.

F^1. Small pinnacles of *Porites* on outer platform about 1 foot below high water.

G^1. The breccia is composed of sharp angular lumps of coral, the interstices being occupied by finer material.

H^1. Roots and pumice 2 feet below top of Hurricane bank.

J^1. Breccia eroded nearly to line of beach.

K^1. Landing place.

L^1. Breccia mass, 9 feet by 6 feet by 2 feet. (T.W.E.D.)

M^1. Ladder of raft washed up here and found August 29, 1897. (T.W.E.D.)

N^1. Recent breach in Hurricane Bank. (T.W.E.D.)

O^1. Swamp with floor of shelly sand. (T.W.E.D.)

P^1. This southern end of swamp is a partly tidal, partly non-tidal, flat of gravel, sand and loam, without vegetation. (T.W.E.D.)

Q^1. Numerous sand patches, sometimes of considerable area.

MAFOLA (Plate 6).

A. Sand, shingle and small rubble on lagoon side. This island has about twenty small cocoanut trees, some not long planted.

B. Two kinds of breccia are noticed here, one being chiefly composed of the normal sized masses, and the other of smaller and newer material. This latter, which is chiefly on the lagoon side, apparently overlies the former, which is harder; both however are now undergoing erosion and occasionally being torn up in small slabs.

LUAMOTU (Plate 6).

A. Sand and gravel intermixed and alternating along here.

B. The breccia rampart in some places forms a battlement and embrasure line. The erosion has been severe.

C. Breccia cap maintains a remarkably even outer cliff line and surface, the latter forming an almost level platform from the cliff to the beach.

MATEIKA (Plate 6).

A. A channel is nearly cut through here, which bids fair soon to separate these two islands at low water. Already there is a water channel at half tide.

B. Big mass of breccia, 7 feet high above the top of the breccia floor.

C. Beach on this side somewhat like that across the island on the lagoon side, the one being less coarse and the other more like an ocean Hurricane Bank than is usual on the lagoon side.

D. Very little shingle or rubble here; all removed.

E. Big block of *Goniastræa favistella* apparently *in situ*, 8 feet by 1 foot by 4 feet above high water.

F. The lagoon beach along here is strewn with breccia and old coral blocks up to 18 inches, quite like a minor example of the outer beach.

G. Dark breccia beach with no sand. About 150 blocks of breccia around here.

H. This lagoon beach is quite like some of the sea beaches in its erosion, as there are several shifted blocks of the breccia here.

FALEFATU or FAIFATU (Plate 7).

A. Breccia covered with a little breccia rubble.

B. Small breccia *débris* makes up the hurricane beach here similar to that at A.

C. Peaks and bosses of breccia and *Porites*.

D. Numerous pumice fragments in the matted roots.

E. Ocean and lagoon waters only separated by 10 yards at high water.

F. Point of breccia, from which all the superimposed material has comparatively recently been removed.

G. The breccia platform is worn smooth by the attrition of pebbles and small worn blocks. The noise in even a moderate wind, made by the rolling of the pebbles and small worn blocks about half tide and over, is deafening.

H. Breccia ends here in a point—sand begins.

J. Gravel here ¼ inch and over in size.

K. Sand and shingle meet here, and for a short distance commingle.

FUNAMANU or FUNAMANO (Plate 7).

A. Breccia *débris* covering platform.

B. White beacon.

C. Lime pit where coral was burnt for lime with which to build the beacon.

C^1. Small outlier of reef breccia, 6 feet by 3½ feet by 1 foot.

D. Flat mass of coral breccia.

E^1. Living nullipore zone here of a rusty brown colour, but flourishing.

E^2. Living nullipore zone here of a rusty brown colour. The zone abuts on the breccia.

F. High projecting mass of breccia, 10 feet by 8 feet by 9 feet above the platform, *i.e.*, 4 feet 6 inches above high water.

G. A number of big trees, Pukavai—*Calophyllum inophyllum*—here 40 to 50 feet high, and 2 feet 9 inches to 4 feet 6 inches in diameter. They are frequented by birds, as are the Fetau trees of Amatuku.

H. Small short breccia cliff.

J. Breccia up to pebble line.

K. Jagged masses of clinkery breccia here.

L. Rounded boulders make up the hurricane beach here.

M. Blocks of *Porites*.

N. Pebbles.

O. Position in which living *Heliopora* was found, 7 inches by 6 inches by 8 inches.

P. Fragments from 3 inches to 9 inches.

Q. Rolled blocks on Hurricane Beach.

R. Clinker field, with deep and numerous small caverns nourishing the large Pukavai trees.

S. Masses of coral 1 to 2 feet above platform, to which some are cemented. The latter probably represent masses *in situ* of *Porites*.

T. Hard breccia slightly finer than that to the east of it. Dip of the diagonal beds in the breccia at 10° to N. 40° E.

FUNANGONGA (PLATE 8).

B. Big boss of breccia 12 feet by 8 feet, composed of smaller material near the top.

C. Block of breccia 5 feet 6 inches by 5 feet by 3 feet. The breccia capping here has many big masses of coral breccia, as at Luamotu and Funafara.

D. A newer formed rock than the main mass of breccia lies unconformably on it, first as a conglomerate succeeded by a newer breccia, which enclosed blocks appearing to have belonged to the older breccia. This is, however, undergoing erosion in common with the whole of the face along here.

E. Large numbers of fragments, thick as well as thin, of new *Heliopora* and *Millepora*, the former a rich dark blue in colour. These, with a little sand and very little old breccia, constitute most of the beaches between the rampart like projections of breccia.

F. Large numbers of breccia bosses help to form the upper beaches between the projections.

G. Cocoanut trees undermined and fallen along this Hurricane Bank.

H. Ordinary clinker field with large and small blocks.

J. Smaller material makes up the clinker field here.

K. Coarse clinker field.

L. Coarse blocks of breccia.

M. Nearly the same as the present beach.

N. Clinker field. Caverns deep and numerous.

O. Pebbles.

FATATO (PLATE 8).

A. Blocks of breccia overturned and inclining to the sea, enclosed in a sandstone and breccia. This has in it old torn up beach blocks, as well as ordinary beach rubble and smaller *débris*; they are lying at the usual beach angle, and on loose beach stones or pebbles, the underside sloping on the beach, but all undergoing erosion in common with the older breccia sheet.

B. Big and high block of breccia.

C. Mass of breccia, the upper portion enclosing various corals which appear to be *in situ*.

D. The sandbank here is 13 feet high above high water, and is the highest sand accumulation on the whole of the islets.

E. Worn pebbles all sizes up to 18 inches in diameter, and some few over.

F. Smooth worn breccia.

G. Comparatively smooth clinker field.

H. Angular and worn blocks of coral breccia, small and large.

J. Breccia cap higher than usual, and eroded to its top.

SOUTH OF MAIN ISLAND OF FUNAFUTI (Plate 9).

A. Well-rolled pebbles along here.

B. Large shifted flat blocks of breccia lying up the Hurricane Bank slope above the breccia cap.

C. The breccia is much worn in places, disclosing several patches of hard foraminiferal sandstone, in which *Tinoporus baculatus* is the chief foraminifer; this often occurs where there is either no breccia above it, or, as is more usual, a thin sheet only.

D. Big boss of breccia projecting beyond the present general line of the breccia cap and 6 feet above high water.

E. Big flat blocks of breccia lying on the Hurricane Bank.

F. Pebbles mingled with the blocks on the Hurricane Bank, most of which are worn.

G. The breccia here is much worn and smoothed by the attrition of the pebbles at L.9.A.

H. There are numerous caverns and pits in this clinker field. The trees also thrive and grow high near them.

J. Big flat blocks here on slope of Hurricane Bank.

K. Large blocks of *Porites* fixed to platform or piercing it.

L. The trees are small and stunted on this sandbank.

M. The breccia cap is seen to extend through from side to side in one sheet here.

N. The breccia at the end of this island is worn down and being eroded, and is of diminishing width and thickness, till very little is left towards the middle of the space between the islands; this space is not for its whole width of one character, but retains near the ocean face, at corresponding distances, much of the character of the usual ocean platform, while towards the lagoon it is more jagged and rough, presenting a somewhat corroded appearance. Thin layers of pumice seen in places along this Hurricane Bank from 1 to 2 feet from top.

CENTRAL PART, ABOUT THE VILLAGE OF FONGAFALE (Plate 9).

A. Beach of large and small well-worn pebbles.

B. *Porites* block, 7 feet by 4½ feet by 3 feet. A pinnacle in the eroding reef 4 feet 6 inches above coral platform.

C. Small hurricane beach of small lumps of breccia mingled with sand.

D. Numerous breccia blocks here, above the top of the breccia cap, up to 2 feet 4 inches in diameter; the coral blocks and the breccia sheet below them are both more or less undergoing solution.

E. Coarse, clinkery blocks of coral and coral breccia.

F. Large blocks of the breccia sheet shifted on to this Hurricane Bank.

G. Escarpment of the breccia sheet 1½ to 2 feet high.

H. Outcrop of the breccia sheet.

J. Sandbank fails southwards and a depression of the surface landwards succeeds it.

K. Blackish sandy soil.

L. Mingled sand and pieces of breccia.

M. Edge of solution of breccia cap.

N. Solution line; hollows with small pits and caverns.

O. Breccia cap covered over with large coral rubble, east of this.

Q. South depression extending from here to the swamp, which may probably indicate some past communication of the swamp with lagoon.

R. Between this and the clinker field the central depression continues.

S. There are slight indications here of an old communication between this central depression and the lagoon, though it is now in part filled up with sand.

M². Here, in the face of the Hurricane Beach, a trench was put in to ascertain if there was any sign of cementation or consolidation having commenced. The trench was begun about 2 feet above high water, about 6 or 8 inches above the breccia cap, and continued to the summit of Hurricane Beach; the material consisted of old and worn coral and of breccia, apparently from the breccia escarpment, at zone O.2.D., and the floor of platform; with it was mingled some more recent coral, with foraminiferal sand and the usual beach *débris*, stones of all sizes and shapes; it was so loose that very slight jarring was sufficient to shake down more and more of the sides. Not the slightest approach to cohesiveness or cementation was observed. [That gave great trouble in keeping up the sides, and caused us to desist before sundown, till shoring up could be resorted to; but the ss. " Archer " came at 4 A.M. next morning, so this was our last opportunity.]

N². Pit sunk by natives 4 feet through clean sand and fine *débris* at top; a few small stones continued from the surface down to within about 18 inches or 2 feet of high water.

O². Pit similar to the last, differing from it only in that streaks of fine foraminiferal sand, 6 to 9 inches, were passed through, unmixed with stones or *débris*.

P². Long shallow excavation made by native prisoners to get material to make road alongside it, through 2 feet of foraminiferal sand of *Tinoporus*, the least worn and best preserved in any of the oldest sand beach deposits I obtained or saw; though not so perfect as quite new tests or shells, the material is more like that at Nukusavalivali and Motungie than any found elsewhere. Below this, stones, breccia, and fragments as one still finds at some sand islands, which begin by being laid down on the worn and thinned down breccia cap, as at the lagoon side of Telele, Funafara, &c.

Q². First Blast.—Barely 18 inches deep. Several pieces of rich blue *Heliopora*, adhering to the under side of the breccia, and embedded in this, sometimes by its edges.

R². Second Blast.—Under breccia-rock outlier, opposite the opening or breach in the high Hurricane Beach adjoining the clinker field, ½ chain east of the erosion line, well out on the platform, in the slightly depressed smooth zone. Numerous pieces of dead blue *Heliopora*, adhering to the under side of the rock thrown up, and appeared to be similar rock to that which covers *Heliopora*, both in the black breccia near Big Bore and in some parts of the Mangrove Swamp.

S². Third Blast.—The charge was placed in a hole 2 feet deep in water, the charge being placed under a projecting portion within 10 feet of the head of a channel, and as far out as I could get at this point without being close up to the head of the channel. Here the full force of the south-east winds plays on this east cape or point of land and reef. It revealed the sandy (foraminiferal) portion of the bed, and brought up fragments of *Heliopora*, but I could not say if they were *in situ*, but as the blast fractured the rock completely, they may have been. The first rock downwards was exactly like the swamp floor, and below that foraminiferal sand was intermixed, similar to that above *Heliopora*, inside the Hurricane Bank, *i.e.*, in the swamp. One other result of these blasts was to prove that the apparently solid mass of the outer platform is not solid, but cavernous, the caverns (as found in our Big Bore) being crowded with molluscs, crabs, echinids, and other small marine forms.

U². Storm beach of water-worn shingle, 3 inches up to 9 inches, and a few still larger.

V². The summit of Hurricane Bank, for 3 feet in depth, consists of blackened flattish coral stones.

W². The back of the Hurricane Bank of rounded stones and loose sand.

X². Narrow strip of Mangrove Swamp. Breccia sheet here, except at bottom, where there is a purplish mud in places. Depressed line of decomposed and corroded breccia and coral; swampy in places.

Y². Dark sandy soil between outliers of breccia at the surface, continuous with the breccia sheet below.

A³. A large proportion of these coral fragments are composed of *Heliopora*, not greatly weathered.

C³. Road or path northwards.

E³. First outcrop, on the lagoon side, north of the village, of the solid breccia sheet. Hard newer sandstone above this, enclosing some small coral blocks.

J³. Outlier of breccia sheet, 2 feet high. This breccia block does not, on its top, show one piece of the

fresher-looking *Heliopora* we meet with in the platform, but, on turning over portions of it, very many fragments are seen embedded on its underneath side.

E^3. Decomposing breccia sheet, exposed and being corroded.

M^3. Mass of coral breccia 8 feet above coral platform, 15 feet by 10 feet, at base, and displaying at its top fine branches of coral; from between these the infilling is being weathered out.

N^3. Another mass of coral breccia, its upper part quite fantastic, 12 feet by 12 feet, at base, with very many forms of coral on its upper side (many of which are right side up, its base firmly cemented on the main breccia sheet. The summit is 10 feet 6 inches above the outer coral platform, which, however, is 4 feet 6 inches below high water (spring tide).

O^3. Large mass of *Porites*, 8 feet by 7 feet by 2 feet high.

P^3. Black mass of fine corals, 10 feet by 6 feet, rising 4 feet above the top of breccia sheet.

Q^3. Flat mass of breccia, 8 feet by 4 feet by 1 foot 6 inches, with coral, apparently *in situ*, on top.

R^3. High mass of breccia, bristling with pinnacles, and with coral embedded on top. Size 15 feet by 11 feet at base and 10 feet 6 inches above coral platform.

S^3. Conglomerate, *in situ*—same level as that on beach to north-west, weathered lumps of it lying about in places.

T^3. Two big masses of breccia, *in situ*, with many delicate forms fractured, but in position of growth, embedded among the breccia.

U^3. Large masses of outlying breccia.

W^3. Native well. *Heliopora* occurs around the sides, *in situ*, 6 inches to 9 inches below high water (spring tide), interspaced with foraminiferal and nullipore sand, and overlain with whitish mud, and a little above the cultivated swamp land, from which it is separated by a few yards only.

X^3. Small grass flat, composed of black sandy soil, mingled with coral and pumice fragments, instead of the usual Hurricane Beach.

Y^3. The Hurricane Bank here has been driven back landwards some 10 to 20 yards, while its height has also been reduced to a foot or so below the line of the pumice pebbles, which are to be seen in its end sections.

MAIN ISLAND, NORTHERN PART (PLATES 10 AND 11).

A. Grass covers and mats together the rubble forming the inner slope of the Hurricane Bank in several places along here, forming quite green patches of some extent.

B. *Tinoporus baculatus* sandstone outcrops along here, bearing a close resemblance to that occasionally seen on the ocean side of this island.

C. *Tinoporus baculatus* sandstone occurs along here reposing on the eroded breccia cap.

E. Big boss of *Porites* 8 feet by 5 feet by 4 feet above the breccia sheet, which it appears to pierce; its summit is 3 feet above high water.

F. Large cakes of breccia, up to 6 feet by 4 feet by 1 foot 6 inches, are lying on the Hurricane Bank, where they appear to have been carried on being removed from the breccia sheet by the waves.

G. Some small bosses of *Porites* firmly fixed on the platform here.

H. Many large blocks of breccia occur among the beach rubble along the Hurricane Bank.

J. Large mass of breccia 10 feet by 7 feet by 5 feet, with many kinds of coral, small and larger, near and forming its present summit; the spaces between the corals are filled in with small *debris* firmly cemented into one mass.

K. Several specimens of *Porites* seen on different parts of the beach apparently *in situ*.

L. Outer channel very angular along here.

M. Boss of breccia *in situ*, 4 feet above high water on the line of the outer part of corrosion zone.

N. Big boss of *Porites in situ* on the Hurricane Bank 6 feet above high water, 10 feet by 5 feet by 3 feet above the pebbles and rubble of the Hurricane Bank which surrounds it.

O. Corals observed embedded in and covered by the breccia *in situ* and almost as perfect, conspicuous among them being a large species of *Montipora*.

P. Small cliff 10 feet out from high-water line; submerged at high water.

Q. The beach along here for a long way maintains the same general character.

R. Block of breccia, 10 feet by 6 feet, 4 feet above high water.

S. Big worn block of *Porites* well up above breccia cap.

T. Only a few projecting piers of the breccia cap along here.

U. There is a considerable depression for a long distance on the reef platform between the O.L.10 and the O.2.B., in which the water, when the tide is out, is from 6 to 18 inches deep, while the O.L.10 acts as an embankment 1 foot to 1 foot 6 inches above it, within which the water on a calm day is uninfluenced by the ocean swell and its surface is without more than a most gentle ripple.

V. Sandstone resting on eroded breccia.

W. Sandstone and fine conglomerate occur near the high-water line.

X. Remnant of sandstone in a few places along here resting on worn breccia.

Z. Bosses of dead *Porites* occur at various distances out on the reef platform apparently *in situ*, none, however, attaining the height of high water.

TENGAKO (Plate 11).

A^1. Old heathen shrine, the outer walls of which are built of flattish stones, specially long stones being used for the corners, the whole interior space between which is filled up to the top with other and more irregular stones. This is the largest and was at one time the most important shrine on this atoll.

B^1. Fan-shaped deposit of coarse coral rubble torn from the breccia and driven with the Hurricane Bank and recent *débris* on to the lagoon platform and over the edge of it into the lagoon itself.

C^1. Breach across island here through which, during high water and very rough weather, the sea is driven.

D^1. Several small bosses of *Porites* extending well out on the reef platform; there are also a few small loose pieces of rock.

E^1. *Porites in situ* 50 yards out on reef platform.

F^1. Breccia 1 foot above high water.

G^1. *Porites* block *in situ* on lagoon platform.

H^1. A strip of sandstone 150 feet along here is being eroded.

J^1. Small patch of sandstone which is being eroded together with the breccia cap on which it rests.

K^1. Several small blocks of breccia cast up on beach, up to 2 feet in length.

L^1. Newer conglomerate here, fine and coarser being eroded with the breccia cap forming the general boundary of the beach.

M^1. Patches of sand alternating with patches of smooth-worn breccia.

N^1. Short projections or headlands of breccia along here, the beaches between which are composed of foraminiferal sand and general beach *débris*.

O^1. High mass of breccia here, apparently *in situ*.

P^1. Thin bedded sandstones enclosing subangular and rounded stones up to 3 inches here and there, with an occasional much larger stone, all overlying the worn breccia and with it undergoing erosion.

Q^1. Coarse worn blocks make up this Hurricane Bank.

R^1. Breccia blocks with some new pieces of coral make up the beach about here.

SECTION VI.

BIOLOGY OF THE REEF-FORMING ORGANISMS AT FUNAFUTI ATOLL.

By Alfred E. Finckh.

(1) *General Description of a Biological Section Across the Atoll approximately from West to East.*

A general description of a Biological Section across the atoll will perhaps best convey to the mind the distribution of the various reef-forming organisms, as regards their relation to the ocean and lagoon respectively.

Beginning at the western ocean face of the atoll, near the southern end of the islet of Fualopa, our section traverses the lagoon and strikes the main island, Funafuti, on the lagoon platform which extends out from the north end of the sandy beach near the village. Thence it passes across the platform and over the main island and ultimately runs out over the ocean platform in the neighbourhood of the "line of plugs" the "permanent reference marks" of Mr. Halligan's report, situated east of the main diamond-drill bore. The western rim of the atoll, our starting point, is of extremely irregular width. The irregularity of outline is, however, mainly on the lagoon side, the boundary of the atoll oceanwards coinciding with the general contour of the atoll. The reef platform in its entire width is approximately of the same level.

The superficial part of the ocean platform will be described first, the deeper parts later. On the ocean side, up to as far in as the wash of the waves reaches at low-water spring tide, the reef platform is densely covered with vigorously growing organisms. Of these the thinly branching *Lithothamnion* is the most abundant. This alga appears in small isolated shrub-like clusters from 1 inch to 5 inches in diameter, and varying similarly in height. Between these clusters many small coralla of the species *Madrepora loripes*, Brook, are seen, while they themselves grow in such numbers and so close to one another that it is impossible, while walking on this part of the reef, to put one's foot down without treading on them. The foundation on which these grow is the solid rock of the reef platform which extends to the very edge of the platform. Near the edge are other coral forms, also the *Lithothamnion* of the lichenous and knobby forms, but no *Porites* nor *Heliopora cærulea*. These all help to form a complex covering of living material for the rocky platform. No one of these species, however, forms patches of any considerable size, each being prevented

by neighbouring species and by the all-invading lichenous *Lithothamnion* from assuming anything like large dimensions. A great struggle for supremacy seems to be going on, the *Lithothamnion*, however, eventually gaining an easy victory over the corals and hydrocorallines. This vigorous growth extends for only 2 or 3 feet downwards at the edge of the reef below the level of low-water spring tide; below this level the reef becomes comparatively destitute of organisms.

Proceeding towards the lagoon the organisms gradually become more scarce, until at a point where the waves no longer reach at low-water spring-tides, the reef is a barren, comparatively smooth platform with but a few detached rock masses which in most cases are not cemented down.

On the lagoon side of the reef all the forms found on the ocean side are represented, but in addition, we get small pieces of the *Heliopora cærulea*, and here and there fungoid corals. This edge slopes down into the shallow water of the lagoon.

The reef platform on which the islet of Fualopa has been formed by the accumulation of sand, coral, and *Lithothamnion* fragments, is of great width, over 1300 yards, jutting out as a long point into the lagoon. The edge of this lagoon platform consists mainly of living, thinly branching *Lithothamnion*. Its almost perpendicular walls show very little life below 2 feet from the surface of the platform. The platform itself consists of dead cemented fragmental material with, here and there, pancake-shaped *Porites*, both the yellow (*Porites limosa*) and the purple variety, lying, for the most part, loosely on it. The walls sink down into 2 to 3 fathoms of water on to the sandy lagoon bottom, which is made up of detached joints of *Halimeda* and the remains of branching *Lithothamnion*.

In close proximity to the platform there are numerous shoals, mostly on the same level as the platform and therefore awash at low-water spring tide. These shoals show at the rim a vigorous growth of every kind of coral found in the locality, including *Heliopora cærulea* and *Porites*: but, as in the case of the reef, there is the same struggle for existence going on between themselves and the predominating *Lithothamnion*. The central parts of these shoals are dead, formed into the solid rock by the binding effect of the *Lithothamnion*, and are studded here and there with small corals, sponges, seaweeds, &c.

Those shoals which are 2 or 3 fathoms below the surface of the water at low-water spring tide, consist purely of coral or hydrocorallines, either *Heliopora cærulea* or the branching *Millepora*, and mostly of one species only. These so-called shoals are merely clusters of growing coral, which having once attained a certain height become overgrown at their roots by the lichenous *Lithothamnion*. The interstices between the branches of the coral are gradually filled in, partly with foraminiferal and other sands, and the foundation is thus laid for the solid reef rock, which consists of the stems of the coral with which the shoal began its existence, foraminiferal sand, and the remains of the branching *Lithothamnion* and *Halimeda*, all being bound together by the lichenous *Lithothamnion*. Even better examples of this process of

The edge of the reef platform on the ocean side traced landwards up to the wash of the waves at low-water spring tides is covered with the lichenous *Lithothamnion*, which here, as in the lagoon, presents the appearance of having had its growth impeded. Both the thinly-branching and the knobby *Lithothamnion* are totally absent.

The following is a detailed description of this eastern rim of the atoll near the main diamond-drill bore. The lagoon platform here is about 165 yards in width. At the end it drops in places perpendicularly into from 2 to 3 fathoms of water, in others it forms a slope, but this is always steep. The bottom below is almost pure *Halimeda* sand. The platform has been formed, as it appears, by the transformation of large expanses of *Heliopora cærulea* into reef rock by the process already mentioned. The dead *Heliopora* is seen everywhere *in situ*, though in most places its presence is obscured by the remains of its conqueror the *Lithothamnion*. The whole has a decidedly barren-looking aspect. At low-water spring tide the platform is left dry, with the exception of several shallow pools, the sandy bottoms of which are about 6 inches below low water. Some of these pools proved to be lying in hollows belonging to holes in the reef platform which were once of considerable size, but which subsequently have been filled up with sand. An iron rod could be pushed down some 5 feet before meeting with an obstacle. The surface platform harbours innumerable Ophiuroidea, numbers of molluscs and sponges, but scarcely any coral or *Halimeda*. The last two occur only in the reef pools, so that they are never completely uncovered by water. The mode of growth of the coral, which was only represented by *Porites limosa*, offers many features of interest. A description of these is given in the Sub-section on the mode of occurrence of the chief reef-forming organisms (p. 137).

Halimeda grows very abundantly in sandy patches of the platform ; it occurs, too, in large roundish masses on the edge of the reef platform, and the submarine wall of the platform is also covered with it. In the latter position here and there minute coralla of *Pocillopora paucistellata* are met with. On the whole the absence of anything like the vigorous growth so characteristic of the western rim, both on ocean and lagoon face, is very striking. The apparent absence, too, of the lichenous *Lithothamnion*, together with the total disappearance of the branching and knobby forms of this calcareous seaweed, is very noticeable.

We now leave the lagoon platform by ascending the sandy beach : the island here, where it has to be crossed in order to reach the ocean platform, is about 200 yards wide. Standing on the Hurricane Bank, we have lying at our feet the ocean platform 300 feet wide, consisting of typical *Lithothamnion* rock. This platform, like the lagoon one, is characterised by its barrenness, but differs from the latter by being divided into conspicuous zones (see plan on Plate 17). The first two of these, the erosion and the corrosion zones, which are totally dry at most low tides, are devoid of life. At about 78 feet out towards the ocean from the foot of the Hurricane Bank the first growth is met with in the shape of non-calcareous seaweed of an inconspicuous

filamentous form and brownish-green in colour. This occurs along the entire length of the platform, parallel to the shore, as a complete strip, like a slippery carpet. This area, indicated as the seaweed zone, is left uncovered by water at low tide several days before and after spring tides. No coral growth is, therefore, found on it.

Between this zone and the edge of the platform lies the *Lithothamnion* zone (see Plate 17). The line of junction between the two is very irregular, depending entirely on the distance to which the waves wash landwards at low-water spring tides. This distance is the limit of *Lithothamnion* growth, and varies with the nature of the surface.

The *Lithothamnion* zone thus formed comprises that part of the platform which is so characteristically interrupted by the channels extending landwards from the edge of the reef. While the surface of the seaweed zone is comparatively smooth and level, that of the *Lithothamnion* zone is exceedingly uneven on account of the slight mound-like elevations formed partly of *Lithothamnion* and partly of encrusting foraminifera like *Carpenteria* and *Polytrema* which almost invariably surround the channels, especially at their terminations. These, like the entire surface, are very much pitted with irregular shallow hollows, which, towards the edge, are inhabited by echinoids. The whole presents an irregularly pitted surface, but with a total absence of sharp edges, every part being smoothed over and rounded off by the growth of the *Lithothamnion*. The only species represented, however, is the lichenous form; the other two are totally absent.* As is the case on the lagoon platform, it has not the healthy looking crimson colour of this variety of *Lithothamnion* when growing on the western rim of the atoll, and it altogether presents a stunted appearance. Of coral growth there is exceedingly little on the surface of the platform; only here and there a small corallum of *Pocillopora grandis*, hardly ever more than a few inches in diameter, and, in most cases, coated to a greater or less extent with *Lithothamnion*. *Pocillopora verrucosa* and *clavaria* are also present, but still less frequently. In the channels, which were in no instance more than 13 feet deep, and therefore easily examined, there was a greater variety of coral, but nowhere in anything like large masses. The walls of most of them showed nothing but *Lithothamnion* growth; the bottom consisted of large pebbles and coarse sand. This was altogether contrary to expectation in view of the fact that this platform is on the windward side of the atoll and fully exposed to the prevailing ocean current. The chief reef-forming corals, *Porites limosa*, *Heliopora cærulea* and the hydrocoralline *Millepora alcicornis* of other localities in this atoll were not once met with alive on the ocean platform in this part of the atoll. The note on Plate 17 as to the occurrence of *Millepora alcicornis* on the line of section A to B, across the channels, relates to a dead specimen of this species.

The evidence for the description of the platform and channels was obtained by

* It is clear, however, from the section afforded by the diamond-drill bore, as well as from large masses of dead reef rock lying on the reef platform north of the main diamond-drill bore, that a branching type of *Lithothamnion* flourished not long ago at this part of the atoll.—T. W. E. D.

walking out to the very edge at low-water spring tides. Its downward slope, however, was investigated from a canoe by means of the water telescope. Such an examination was, as a rule, practicable only during the monsoon season, when, the S.E. trade wind having been replaced by the N.W. monsoon, this eastern part of the atoll became temporarily the leeward side, so that the sea off this part of the reef platform was comparatively smooth. By paddling up to within a few feet of the position on the edge of the reef, which was previously examined from the shore, we saw the rock-masses separating the channels slope down gently into from 3 to 5 fathoms of water. At that depth these ridges unite with the troughs between them to form the general slope of the atoll. There is no sign of overhanging rocks or buttresses. The loose material noticed in the channels on the platform does not extend down the slope, for in front of the ridges seawards it has entirely disappeared, and the reef presents a solid floor of *Lithothamnion* rock. The surface of this rock is extremely rough and uneven, but its inequalities do not interrupt the general and gradual downward slope of the atoll. The lifeless appearance of the reef-rock continues in a downward direction; of coral there is less than ever, and where it does occur it is in small isolated pieces. Here and there are clusters of *Halimeda* and of small non-calcareous green seaweeds, but neither are very abundant. Besides the general uveneness of the *Lithothamnion* rock there are present the innumerable small cavities already mentioned as occurring on the platform, of irregular shape, mostly longish and tortuous, and invariably inhabited by echinoids. Every individual of these, whether large or small, seems to fit perfectly into the cavity inhabited by it, so as to suggest that the cavities are their work. By means of the water telescope this ground could be surveyed down to from 10 to 15 fathoms. Dredgings were not carried on in this locality; but a description is given in the following sub-section of material dredged in other parts of this atoll from various spots on the ocean slope of the atoll.

(2) *Comparison of the Platforms, Slopes, and Islets of Different Localities on the Atoll.*

The ocean platform as described near the islet of Fualopa is typical of the leeward rim of the atoll; that near the 1897 boring is typical of the windward rim.

The characteristic features of the former are:—(1) The enormous quantity of the branching *Lithothamnion*. (2) The vivid colouration of the *Lithothamnion*, which is here represented by all three forms. (3) The great abundance, near the edge of the coral, of the small brownish species of *Madrepora loripes*. (4) The smallness in dimensions of all species represented. No one species occupies large areas, but is represented as isolated coralla surrounded by other forms. *Heliopora cærulea** and

* As far, however, as could be judged by means of the water telescope, a considerable amount of *Heliopora cærulea* appeared to be growing at a depth of a few fathoms on the lagoon side of the reef between Fuafatu and Fualopa.—T. E. W. D.

The islets on the two sides of the atoll have themselves their characteristic differences. In both cases they are accumulations of *débris* on the rim, and it is this *débris* which enables us to classify them into leeward and windward islets. The former agree in their constitution entirely with their present biological surroundings, being large accumulations of the fragments of the branching *Lithothamnion*. Intermixed with this is a quantity of foraminiferal sand, as well as fragments of the frailer corals at present growing in the neighbourhood, together with *Halimeda* remains and shell fragments, the whole forming a coarse sand. These large heaps of sand begin quite abruptly on the platform without the intervention of a breccia* zone, and this accounts for the fact that the shapes of the islets change from time to time, as stated by the native inhabitants.

The windward islets are, as already stated, also accumulations of *débris*, but this is not, as it is in the case of the leeward islets, the direct product of living organisms. The boulders and pebbles heaped up on the Hurricane Bank indicate that they were once part of the general *Lithothamnion* rock. Sand on these islets is the exception; it consists, where present, mainly of *Halimeda* remains together with a large percentage of foraminifera.

The slopes lagoonwards are in all localities sandy; purely *Halimeda* to the east, and containing on the west besides the *Halimeda* plentiful remains of *Lithothamnion*. The bottom of the lagoon within a very short distance of the rim, in every instance where dredgings were carried on, was found to consist of almost pure *Halimeda* remains, with a small admixture of foraminifera, as already described by Mr. F. CHAPMAN.

The examination of the ocean slopes is a somewhat difficult matter. In four different localities, however, satisfactory information was obtained—at the island of Funafuti near the 1897 bore; off the rim between the islets of Funafuti and Fatato, at the islet of Pava to the north, and off Fualopa on the western side of the atoll.

The observations at the first of these localities have been discussed in the preceding sub-section. The other localities differ only in minor details from it. Between Funafuti and Fatato, where the reef rim, as described above, is very narrow and consists of a "flat" from lagoon to ocean face, there is no slope oceanwards from the rim surface, but the reef flat with its irregular edges, its buttress-like projections and its intermediate channels, ends in vertical walls one or two fathoms deep, at which depth the general submarine slope of the atoll begins. Considerable quantities of isolated coralla of *Pocillopora* (? *sp.*) exist here. A few specimens of the mushroom coral, *Montipora incognita*, are present, as well as the only example of a "brain coral" (about 4 feet in diameter) noticed on the atoll. There is no sand present, but pebbles lie in the hollows of the uneven slope. As the depth increases, the ground becomes more even and shows many small isolated growing corals, with here and there a patch of *Halimeda* and non-calcareous green seaweeds.

* Sandstone formation and breccia (the latter only lagoonwards) are occasionally met with, but they are quite the exception on the western rim of the atoll.

lichenous form ; (*b*) the thinly branching species ; (*c*) the lichenous variety characterised by its stony knobs.*

(*a*) The lichenous form is exceedingly common. It is found on the lagoon platform and on the ocean face of the entire rim, as well as on all the shoals. Its upper limit of growth is approximately that of low-water spring tides, or as far as the waves usually wash at this level. It is easily recognised down to 3 to 4 fathoms, but beyond that depth it loses its characteristic colour, and being thus obscured its presence cannot be detected with certainty by means of the water telescope. It is, however, indubitable that a lichenous or encrusting type of *Lithothamnion* flourishes on the submarine slope of the atoll even down to depths of 200 fathoms. This was proved by the evidence afforded by fragments broken off *in situ* by the chisel down to such depths and then caught in the tangles and brought to the surface during the dredging operations carried on both during the 1897 and 1898 Expeditions.

(*b*) The second variety, the thinly branching form, is exclusively confined to the western, *i.e.*, the leeward rim. There it grows very abundantly on the surface of the ocean and lagoon platforms, its upper limit being, as in the case of the other forms, that of low-water spring tides. On the ocean walls of the platforms it was not observed to occur more than a foot or two below low water; in the lagoon, however, large areas were noticed in 2 to 3 fathoms of water. It was never obtained alive during dredging operations in the lagoon, which were carried on from 8 to 26 fathoms, so that bathymetrically it seems to have a very limited range, whereas geographically its distribution is now limited to the western rim.

(*c*) The third species of *Lithothamnion* is the lichenous form with its stony knobs. This variety was also found to be totally absent from the eastern rim, although dead fragments were common on the sandy beach near the village. It is very common on the lagoon reef platform between the islets of Mulitefala and Fualifeke and on the shoals lying off it. Again, it is met in association with the thinly branching form on the western rim of the atoll. Its bathymetrical distribution seems to be the same as that of the thinly-branching form.

During the ocean dredgings, loose cakes and flat pieces of calcareous rock up to 1 foot in diameter and about an inch in thickness were frequently brought up from considerable depths, some from over 90 fathoms. These were covered with various encrusting organisms which are certainly *Lithothamnion*, but it will require microscopical examination before their relation to the above three surface species can be determined.

As already stated, fragments of similar *Lithothamnion* were frequently obtained from depths of over 100 fathoms *in situ*. That they were *in situ* is proved by the following facts :—(*a*) The pieces showed fresh fractures which prove that they have been detached by the chisel or hemp-tangles. (*b*) They were associated frequently with various deep-sea corals, such as *Neohelia* (2), *Balanophyllia*, &c.

* See also pp. 137, 145, 155, *et seq.*

Expeditions of 1897 and 1898, shows that its occurrence on the seaward slope is rare, and that, as regards its present distribution at Funafuti, it is a lagoon rather than an ocean coral.

The same predominating character of *Heliopora cærulea** was observed on the home voyage of the Expedition in the lagoon of the atoll of Onoatoa, in the Gilbert group, the only other lagoon island examined by the writer. At the four Gilbert islands visited which have no lagoons, not a single case of *Heliopora cærulea* on the slopes, near the landing places, was noticed.

(*b*) The Hydrocorallinæ are the next in importance. Of these the branching form *Millepora alcicornis* is largely represented in the lagoon, and is not restricted to any particular part thereof. It was not observed on the ocean slopes or ocean platforms except quite close to the true passages, in which it was very abundant. *M. complanata*, the more massive of the two, is still more widely distributed, but does not occur in patches of any extent. The eastern ocean face of the reef platform, as far as to the northern passage west of the islet of Pava, was the only place in which it was seen in considerable ridge-like masses.

(*c*) Of the *Porites* family both the yellow *Porites limosa* and the purple *Porites* (? *sp.*) came under this category. But with the exception of the lagoon platform of the main island they were not seen to form large continuous masses. As small pancake-shaped coralla they are fairly frequent on all portions of the reef platforms; small colonies are always found on the shoals. They were not noticed to occur on the ocean slopes. The immense numbers and size of the blocks of dead *Porites* occurring on the S.W. portion of the atoll are specially noticed in the geological report.

(*d*) *Madrepora loripes*, BROOK, was specially abundant, as already stated, on the western rim of the atoll near Fualopa, &c. It and the remaining coral-forms are insignificant as reef formers.

(*e*) *Pocillopora cæspitosa*, DANA, as already mentioned by Mr. C. HEDLEY,† was abundant in the shallow water of the lagoon on its eastern side, while *Pocillopora grandis*, *P. verrucosa*, and *P. clavaria* were not infrequent on the ocean face of the eastern side of the atoll.

P. paucistellata was fairly numerous in the shallow water of the lagoon on the eastern side of the atoll. Among other reef-forming types the astræan corals seemed of far less importance at Funafuti than at most other coral reefs.

Distichopora, which in some reefs is sufficiently numerous to rank as a reef former, was not found by me alive in any dredgings at Funafuti. Mr. HEDLEY records‡ the

* Messrs. DAVID WOOLNOUGH and POOLE observed on their visit to Nukulailai (the atoll next south of Funafuti) in 1897 that *Heliopora cærulea* was very widely distributed at that atoll also, being far the most important reef-forming organism there among the corals.

† Australian Museum, Sydney. Memoir III. 'The Atoll of Funafuti,' Part 6, p. 352.

‡ *Loc. cit.*, Part 8, p. 531.

fact that a dead specimen of *Distichopora rosea* was collected by him on the beach of Funafuti.

(4) *Foraminifera.* The remains of these Rhizopoda are present in all the beach sands, as well as in the lagoon sediment in close proximity to the shores. Pieces detached from any part of the reef platforms show them to have taken an important part in the formation of the reef rock. The somewhat difficult task of ascertaining the distribution of this factor in reef formation was not attempted by me. Mr. FREDERICK CHAPMAN'S papers supply detailed information upon this point.*

(4) *Mode of Occurrence of the Chief Reef-Forming Organisms.*

The order of the previous section is here followed. (1) *Lithothamnion.* Of the three forms occurring, two are distinctly lichenous; the third is fruticose, growing erect in isolated pieces, and branching in a shrub-like manner. The last-named has therefore not the binding effect of the other two forms, and, as a reef-forming organism, must be classed with the corals, playing, like them, a passive part. The lichenous *Lithothamnion* and the knobby form, on account of their incrusting habits, play a very important part in the formation of the reef. Being purely incrusting, they require for their growth a foundation over which they can spread. The limit of such foundation is the limit of their extension. For further growth the presence of additional foundation is required. Should such be present in very close proximity to the original one, the *Lithothamnion* would reach across to it and continue its incrusting work, neighbouring masses being by this means firmly united together. The *Lithothamnion* by no means confines itself to lifeless material, everything that crosses its path is overgrown and overpowered. Excellent illustrations of this are afforded by the *Pocillopora* corals on the ocean platform of the Island of Funafuti already mentioned. The separate branches of this coral are widely separated; the nullipore does not attack it at the basis of the branches and grow upwards, but expands over the surface of the coral from tip to tip of the branches, leaving hollow spaces underneath. These spaces eventually fill up, so that part of the coral which has been killed by the overgrowing *Lithothamnion* becomes a solid mass. Whether this takes place by infiltration or by precipitation, or by the actual increase in thickness of the *Lithothamnion*, is a geological question. The thickness of an individual crust of *Lithothamnion* noticed at Funafuti varies from a covering too thin to be detected at its edges even by touch, to a layer of 1 inch in thickness. A satisfactory determination was not arrived at as to whether growth was taking place in thin layers on the surface only, or whether the whole thickness was actually living. Certain observations, however, to be quoted in the sub-section (6) on the "Rate of Growth," point to the former method of growth.

(2) *Halimeda.* In regard to the mode of occurrence of these algæ, the roundish

* 'Linnean Soc. Journal,' Zoology, vol. 28 (1900–03), pp. 1, 161.

patches of the eastern lagoon platform, already mentioned in Sub-section (1), indicate that, when growing on a surface level enough to allow of an accumulation of loose material, the *Halimeda* builds up on its own *débris*. One of these patches, when broken into, shows the actually living joints, which are indicated by their green colour, to occupy only the upper 4 to 6 inches of the mass; below this the mass is made up of the dead, but still connected, joints of the plant, which pass downwards gradually from the coarse into the fine *Halimeda* sand of the bottom of the lagoon. This process of heaping up of *Halimeda* sand is undoubtedly going on throughout the lagoon and on the ocean slopes. On the wall bounding the lagoon platform of the eastern rim of the atoll it was observed that the *Halimeda* forms an almost continuous living fringe.

(3) *The Corals and Hydrocorallines.*—Of these corals, the mode of occurrence of which is of importance in the formation of the reef, we have as in the previous chapter, (*a*) *Heliopora cærulea*; (*b*) The *Millepores*; (*c*) The *Porites* family; (*d*) *Madrepora loripes*, and (*e*) *Pocillopora*.

(*a*) The *Heliopora* is of primary importance.

At the present time it is mainly this coral which is laying the foundations for further additions to the land in the shape of shoals and platforms in the lagoon. Its shoal-like clusters have already been mentioned in Sub-section (1) as occurring on the western rim of the atoll. The highest parts of those shoals, or clusters of coral, which are still from 2 to 3 fathoms below the surface of low-water spring tide, consist entirely of this coral. Once, however, risen to within a few feet of low-water level spring tide, their summits become overgrown by the lichenous *Lithothamnion*. The interstices between the branches of the coral become filled in, so that finally a continuous and compact rock results, with a surface a comparatively smooth plane, which eventually reaches the level of low-water spring tide. The rock consists of the stems of the coral with which the shoal began its existence, of foraminiferal sand, of the remains of the finely branching *Lithothamnion* and of *Halimeda*, all bound together by the agency of the lichenous *Lithothamnion*. By this process shoals arising on the edge of the reef platform are added to it as solid rock.

The remarkable uniformity of level of the tops of the reticulating branches of the *Heliopora*, as illustrated by the dead remains in the Mangrove Swamp at Funafuti (see Plate 18) and, but less clearly, on all the lagoon platforms, is due to the surface of the water forming a sharp plane of limitation to their upward growth. In deeper water where there is no limit to its growth in height the coral expands irregularly upwards as well as outwards.

A somewhat singular occurrence of *Heliopora cærulea*, growing 2 feet above low-water spring tide, was observed in a shallow basin on the reef at the north end of the Islet of Amatuku. Both *Heliopora* and *Porites* were seen to be growing there in a healthy condition. At high tide the outline of the basin is entirely obliterated, but as the tide retreats a distinct rim becomes visible, hemming in a sheet of water, the level of which only falls a certain depth with the tide and remains stationary during the rest of the

Similar patches of the *Porites limosa* are seen a little to the south of the obelisk. These are not so extensive but, being in deeper water and therefore never uncovered, they assume a greater thickness. Their upward growth is not interfered with by the level of the tides, so that their uppermost portions are not in the same plane; nor does the *Lithothamnion* as yet encroach upon them.

In other localities the *Porites* on the platforms are not seen to form continuous masses, but their coralla invariably assume the pancake shape, and have always a depression near the centre, varying with the size of the colony. This depression contains living *Lithothamnion*, which forms the centre from which the alga will eventually extend over the entire surface of the *Porites*, converting it thus into the reef rock of the platform. *Porites* of this definite shape and these habits are met with very frequently, but the difference in shape and mode of expansion of these specimens as compared with those growing in deeper water points to the fact that their presence in these former situations is accidental, while their growth is forced and unnatural.

Madrepora loripes, BROOK, and the different varieties of *Pocillopora*, especially the species *P. cæspitosa*, do not merit further description than that already given.

(4) The last reef-forming organisms, the *Foraminifera*, were not studied by me.*

(5) *Reef-Destroying Organisms.*

In the case of the living corals no organisms were observed to burrow in, or to feed on, them, so as to cause their destruction, or otherwise interfere with their growth. The branching corals are particularly free from any such attacks. The massive corals, such as *Porites*, and of the Hydrocorallinæ, the stout *Millepora complanata*, almost invariably harbour molluscs, both bivalve and of the tunnel-forming type, together with commensal cirripedes. But all of these, more or less, remain stationary, and do not interfere seriously with the welfare of the coral, though they, of course, enlarge the tube or cavity in which they live at its expense.

The *Lithothamnion* rock, however, especially on the eastern rim, is interfered with by burrowing organisms to a great extent, so that these must be a considerable factor in the economy of the reef. The chief of these destroyers is a Gephyrean and an *Aspidosiphon* which is from 2 to 3 inches in length, but very thin, and possesses a long retractile proboscis by which it is seen at low tide to feed off the *Lithothamnion* covered rock immediately surrounding its abode. By these the eastern ocean platform near the edge, indeed the entire *Lithothamnion* zone, is literally riddled. A small piece of the reef rock a few inches in diameter when broken off will show as many as 10 or 15 of these animals, and, before it can be quite severed from the rest of the rock, the bodies of these have either to be dragged out of their habitations or to be separated.

* See Mr. F. CHAPMAN's description, 'Linnean Soc. Journal' (Zoology), vol. xxviii. (1900–03), pp. 1, 161.

instruments and apparatus, upon the nature of which it is hard to decide before becoming familiar with the work on the spot, when, of course, every opportunity of obtaining the necessary apparatus is gone. As it was, we employed such as was on hand, viz., a steel-yard, capable of weighing from 5 up to 120 lbs., ordinary scales capable of weighing from $\frac{1}{4}$ oz. up to 4 lbs., and an apothecary's scales capable of indicating a difference of 5 grains. Besides these instruments, rules and callipers were available.

The experiments were carried on in the neighbourhood of the drill camp on the main island, both on the lagoon and ocean platforms. This locality, unfortunately, turned out to be the least favourable spot that could possibly have been selected on the atoll for this work, both on account of the scarcity of coral, and the total absence of such forms as the *Heliopora* and the branching and knobby varieties of *Lithothamnion*, which from their importance as reef builders called for special investigation. The eventual discovery of localities on the atoll eminently suited for the work, such as Fualopa and Pava islets, was not made before a considerable time had elapsed, when it was too late to begin a fresh series of observations.

In spite, however, of these drawbacks, the results obtained are decidedly interesting, although it is to be regretted that no information was obtained in reference to the above-mentioned species of *Lithothamnion*, both of which, from their mode of growth, are much more suited for the purposes of measurement, than the lichenous form.

In regard to the weighing, the chief difficulty arose from the fact that broken-off pieces of the organisms had to be experimented upon, and these, in order to be secured, had to be placed in boxes, so that, although they were kept in the same locality, yet the conditions were by no means natural. As to the scales themselves, only the largest were suitable for weighing the coral while immersed in water, so that, as far as the smaller pieces of coral were concerned, this method of weighing had to be abandoned. The weighing in all cases, however, was carried out under identical conditions, the water being allowed to drain off for the same length of time. Thus, the results may be looked upon, in spite of this drawback, as fairly accurate.

Measuring was much more easily carried out. It gave better and certainly more accurate results. But, considering that the experiments extended over less than five months, only the fast-growing specimens were expected to show an increase of an order such as could be detected by this means.

Altogether the following corals and algæ were experimented on, and data therefrom inferred,* *Porites limosa*, the yellow *Porites* of the lagoon platform; *Hydnophora microcona*, *Astræopora ocellata*, *Pocillopora paucistellata*, *P. grandis*, *P. verrucosa*, *Millepora complanata*, *M. alcicornis*, and *Montipora incognita*. Of the calcareous algæ, *Halimeda* and lichenous *Lithothamnion* were placed under observation.

* For the specific determination of these corals I am indebted to the kindness of Mr. THOMAS WHITELEGGE, of the Australian Museum, who described the corals obtained by Mr. C. HEDLEY during the Funafuti Expedition of 1896. (Australian Museum. Memoir III. Part 6, pp. 349–368.)

(1) ***Porites limosa.*** A considerable block of this coral, which was dead at its base, and could therefore be detached from the reef rock without in the least interfering with the live portion, was secured by fastening it to a board, and then the whole was lowered into about 3 fathoms of water at high tide, the same depth from which it was obtained. The piece had been obtained near the spot where the experiments were carried on. By means of a rope attached to a float the coral could be hauled to the surface for examination whenever required. It, together with the board and attachments, weighed, under water, 22 lbs. at the commencement of the experiment. At every weighing both coral and board were scrupulously freed from the sediment, crabs and molluscs, which were continuously settling on them.

Throughout the four months during which this coral was under observation a steady increase of weight, amounting to 47·27 per cent. per annum, was experienced.*

(2) *Hydnophora microcona.* This coral has a peculiar encrusting tendency and is often found growing over dead portions of its own corallum. A piece well suited for measuring purposes was discovered on the ocean platform near the drill camp. The living coral was spreading from two sides over a dead piece. When first inspected the two approaching sides were distant 3 thirty-seconds of an inch. After 55 days they had met. If we assume that the two sides were approaching at the same rate, growth to the extent of 1 inch in 39 months was indicated.†

(3) *Astræopora ocellata.* A specimen of this coral was under observation. Certain areas were pinned out by means of glass pins so that any possible expansion might be traced. Not the slightest increase in the areas was noticed. It was observed, however, that new calices were forming in the intervals between those already existing Certain of these, while at first indicated by mere punctures, had after three months attained very nearly to the size of the functional calices. This coral, like, as it seems, all other forms, increases laterally in the shape of a thin expansion at its free edge immediately where it overlies the dead foundation on which it grows. Although this fact was noticed, measurements were unfortunately not taken.‡

(4) *Pocillopora grandis.* A young corallum of this species, about 2 inches in diameter, was kept under observation *in situ* on the ocean platform. This specimen, which is preserved in the collection, shows well the above-named method of

* The following are the details of this increase:—

	Weight in lbs. avoirdupois.
August 1, 1898	22
August 26, „	23¼
September 9, „	23½
September 12, „	23¾
October 8, „	24½
November 14, „	25

† This specimen was preserved, and has been forwarded to London.

‡ This specimen also was preserved, and has been forwarded to London.

expansion. Measurements were taken in four different directions, and these indicated an average rate of extension of remarkable rapidity, *i.e.*, 1 inch in 13·5 weeks.

(5) *P. verrucosa.* At the time of the commencement of the experiments no specimen of this species was found large enough to allow of its being weighed under water on the heavy calibre scales, which alone are suited for such work. Resort, therefore, was had to fragments, and these, to suit the scales, could not be more than 500 grains in weight. Here, as in all cases where small broken-off pieces were used, a most startling increase was noted. In this one it amounted to 150 per cent. per annum.

In reference to this and all other similar large increases, it must be stated that on all broken-off pieces the entire fractured surface was found to become rapidly coated by a continuation of the general fleshy cœnosarc of the coral, a coating which soon gave rise to polyps, so that the increase in weight is by no means due to a natural growth of the coral. The fractured surface gave an additional area for growth which was not present under natural conditions. This undoubtedly indicates that the method of weighing is, under these circumstances, by no means a trustworthy source of information in regard to the rate of growth.

(6) *P. paucistellata.* In the case of this tiny coral a similarly large increase was experienced. For the reasons above stated not much importance is to be attached to the result.

(7) *Montipora incognita.* A specimen of this mushroom coral was kept under observation. Measurements in three different directions showed an average increase of 1 inch in 35·7 weeks. In one of the directions measured the increase in three months was as much as half an inch.*

(8) *Millepora alcicornis.* This branching stinging *Millepore* offers great facilities for the observation of its growth. When its smooth laterally-compressed branches come in contact with an opposing one, firm union takes place. Between such approaching surfaces very accurate measurements can be taken. An average increase of 1 inch in 34·7 weeks was observed.

Besides actual growth, this hydrocoralline was noted to have a marked tendency to coat, with its own calcareous material, any object with which it comes in contact. The specimen, on which the above growth was determined, in two months completely covered the cord by means of which it had been fastened down. On the same piece some fragments of *Halimeda,* which had become entangled in it, were entirely coated over.†

(9) *M. complanata.* This massive ridge-like hydrocoralline was unfortunately not of frequent occurrence near the camp. The small broken-off pieces obtained showed an increase of 16·5 per cent. per annum. This result was not considered satisfactory,

* The specimen is in the collection forwarded to London.

† The specimen is in the collection forwarded to London.

since the pieces did not seem to be thriving after they had been removed to the place of observation.

(10) Of the *Lithothamnion*, experiments were made only on the lichenous form. It was not found possible to obtain even the slightest indication of increase during five months of patient observation, by any one of the methods adopted, viz., by measuring between the opposite points of the channels on the platforms, by the insertion of glass pins and rods, by the employment of markings and scratchings in the *Lithothamnion* substance, by the implanting upon it of foreign objects, so that the growth indicated by strength of cohesion might be noted, and by sundry other means.

Certain information, however, was gathered which, although it throws no light on the rate, yet makes clearer the mode of growth of this alga.

Its landward limit is, as elsewhere stated, the wash of the waves of low-water spring tide. Occasionally one finds, just outside the limit, isolated patches from 1 to 6 inches in diameter, which, like the rest, are of a bright pink colour, and very well defined from the remainder of the reef rock. Yet so extremely thin are these growths that it is quite impossible to feel, much less to measure, their thickness, and were it not for their colour there would be nothing to indicate their presence on the platform. Several of these patches were measured from week to week, and an average growth of expansion of 1 inch in 10 months was determined, while in one instance an extension outwards at the rate of 1 inch in 6·56 months was shown.

Again, on several occasions the weather at spring tide was exceedingly calm, so that the wash at lowest ebb did not reach up to its usual mark, with the result that considerable areas of *Lithothamnion*, especially on the mounds surrounding the heads of the channels in the seaward face of the reef platform, remained quite dry and exposed to the sun for upwards of an hour. This exposure caused them to turn completely white, indicating thereby the death of the alga so affected. After a few days, however, the pink colour began to reappear, always having for its starting point some notch in the edge of the white patch, or some slight hollow, or small hole in its mass. Growth from these centres would proceed concentrically until, eventually, the several advancing portions met and again completed the sheet of colour. This would occupy less than two weeks. Several specimens of this kind, showing the dead and regenerating portions, were preserved in spirits, formalin and glycerine.

Extremely minute as it is, the growth indicated by the two above-mentioned observations must mean in years an addition to the atoll. Indeed, it seems quite possible that the mounds so conspicuous at the ends of the channels, in the very places where the above-mentioned observations were made, are partly due to this growth of layer upon layer of new material.*

(11) *Halimeda*. Of the other Algæ this great *débris* producer received special

* Foraminifera, such as *Polytrema* and *Carpenteria*, contribute largely to form these mounds.

attention. All methods that could be devised were adopted to obtain some idea as to its rate of growth. One experiment, however, the starting point of which was a mere accident, proved so successful as to cause all others to be abandoned. It gave all the information desired.

One of the boards employed as supports for the corals under observation had a number of holes bored through in order to decrease its buoyancy. On lowering it one day it was accidentally allowed to rest on a cluster of *Halimeda*. Shortly afterwards it was noticed that a small branch of this seaweed was protruding through one of the holes. The board was then allowed to remain in that position for six

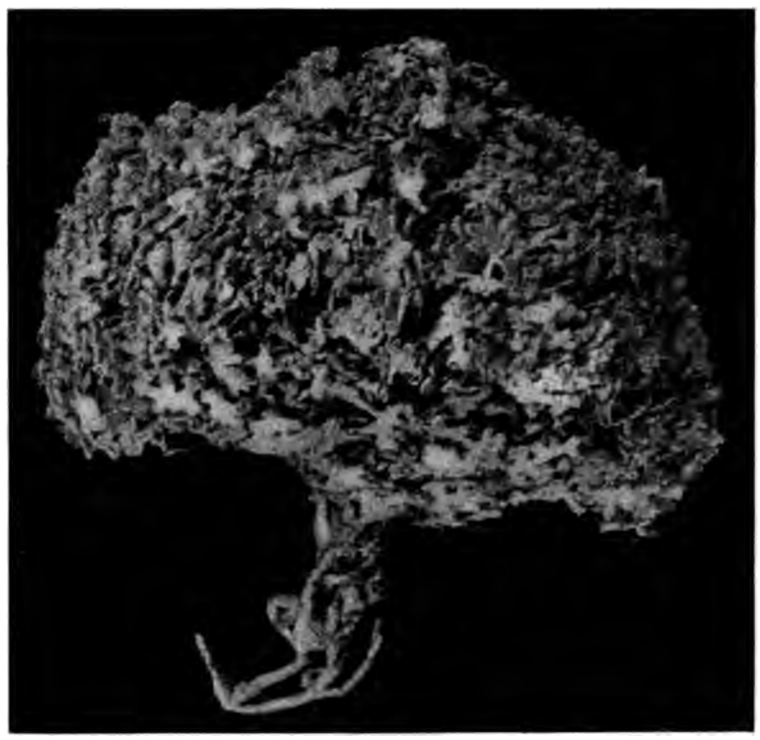


Fig. 19.—Six weeks' growth of *Halimeda*.

weeks, at the end of which time this branch had produced on the board, above the hole, a cluster of *Halimeda* some 3 inches in height and of an equal thickness. On drying, the piece represented 14·38 grammes of calcareous matter. This remarkably rapid growth seems quite to agree with the presence, discovered during the lagoon borings, of the enormous beds of *Halimeda* remains in the lagoon.

As regards the corals, the rate of growth noted is considerable enough to be appreciable from year to year, indeed large enough to cause constant alterations in the contour and the size of coral islands. Yet, so far as can be ascertained, no changes, due to such growth, have taken place on Funafuti or on any of the islands of the Ellice or Gilbert groups since their discovery. In regard to this apparent contradiction the following explanation might be given :—Every species of coral, like

every animal and plant, has a limit to its growth, that is, as far as the individual corallum is concerned. Thus *Pocillopora grandis*, the species on which such rapid growth was observed, was never met with much above 12 inches in diameter. So that the rate of growth determined seems merely to indicate the time required for the attainment of what may be termed the adult size.

In the preceding pages an attempt has been made to show that corals are not active reef builders. A coral, once established, adds to the coral island by its growth only in the same way as a tree, once established, adds by its growth to the extent of a forest. The growth of the coral island cannot be estimated by the rate of growth of the individual corallum, for, unless a coral, no matter of what dimensions, be used by the *Lithothamnion* as a foundation for its growth and be cemented by it to neighbouring corals, &c., it cannot enter as a whole into the formation of the reef rock of the island, although what is left of its fragments after its general decay may help to form the non-consolidated dry land. On the other hand, if a corallum be taken possession of by the *Lithothamnion*, which will cause every interstice, as well as every space between the branches, if present, to be transformed into one solid mass, it will be the initial cause of a solid addition to the coral island, to the extent of its bulk at the time when the *Lithothamnion* had succeeded in over-growing it. And this bulk will depend entirely on the age of the coral when overgrown, since in the young state it will be small, in the older, larger.

Considering that it has been proved that the growth of the coral is so much more rapid than that of the *Lithothamnion*, the question may be put, What is there to prevent any corallum from attaining its adult size? While the *Lithothamnion* is encroaching upon it from one side, plenty of time would be available for extension of the coral to take place in the opposite direction. Although no reason whatever could be discovered, it seems to be the fact that a coral once attacked by the *Lithothamnion* remains stunted; for even quite small coralla, of *P. grandis* for instance, were met with completely encrusted.

As to the conditions, favourable or unfavourable, to the production of numerous individual coralla, as distinct from the rate of growth of individual coralla, nothing whatever was discovered. Those great factors, to which one naturally looks, ocean currents and the direction of the trade-winds, appear to have nothing to do with it, at least at Funafuti. It is to be regretted that no more definite statement can be made in regard to *Lithothamnion* growth. The estimate, however, of its extremely slow growth, seems to be confirmed by the fact that only on rare occasions is the *Lithothamnion* met with in a state which indicates that the deepest laminæ are of recent origin in layers more than three-quarters of an inch in thickness.

It may be stated here that on some of the Gilbert Islands, Onoatoa for instance, a very thickly digitated *Lithothamnion* seems, in places, to be forming the entire ocean platform. These islands were visited on the home journey of the Expedition,

but a stay of often only a few hours at one particular island did not allow of minute examination.

To future investigators into the question of *Lithothamnion* growth it might be suggested that attempts should be made to fasten down on to flat surfaces of living *Lithothamnion* fairly thick glass plates with holes of varying sizes. It will be found that the *Lithothamnion* immediately in contact with the glass will perish, while it will continue to grow upwards in the holes. So that if the thickness of the plates is given, the growth might be estimated after a number of years. The plates might be fastened down to the reef rock by means of short glass legs cast in one piece with the glass plate.

(7) *Experiments On:—*(A) *Exposure of Coral and Lithothamnion to the Sun.* (B) *Amount of Carbon Dioxide in Lagoon and Ocean Water.* (C) *Evolution of Gases by Coral.* (D) *Observations on the Temperatures of Water.*

(A.) The experiments in connection with the amount of exposure to the sun's rays which coral and *Lithothamnion* are capable of enduring were carried out systematically only in the case of *Porites limosa* (the common species of the lagoon platform), *Pocillopora verrucosa* and *P. grandis* of the ocean platforms and of the lichenous *Lithothamnion*.

Of these the *Porites* alone were able to withstand exposure beyond a very limited amount of time. They were found to be unaffected by an exposure of as much as twelve hours, by which time the coral seemed perfectly dried up, yet on replacing it in water the polyps revived and continued to live. All the other forms were dead after less than two hours exposure, immediately after they had become dried up externally. Death was indicated in the case of the coral by the shedding of the gelatinous coating, in the case of the *Lithothamnion* by the disappearance of the pink colour. Certain specimens of *P. verrucosa* were exposed in their upper parts only, while the main stem was still immersed. The result was that they were destroyed exactly down to the water line.

The results of these experiments agreed with inference from general observation, that the *Porites* alone were able to survive exposure to the sun. This exposure took place at low-water spring tide in calm situations where the waves did not wash over them. Other corals were found above the low-water spring tide only in situations where they were washed by successive waves. The external gelatinous coating of the *Porites* seems much thinner than that of other corals, a circumstance which may play some part in their power of resistance to the sun and air. During these experiments it was evident how very necessary a constant supply of fresh sea-water is to the coral. Specimens were kept in enamelled basins for purposes of observation, but it was found invariably that, even when the water was changed every three to five hours, they did not survive the second day.

(B.) Experiments on the amount of carbon dioxide in the water of the lagoon and the ocean.

The method of dealing with this question was, for the want of better appliances, a somewhat rough and ready one. Yet, since the experiments were carried out on the same lines, the results, for purposes of comparison, may be considered accurate. A saturated solution of lime-water was added to the water to be treated in the proportions of one of the former to three of the later. The lime was obtained by burning coral fragments in the furnace of the boiler of the drill machinery.

The amount discovered in the water of the ocean is large, and its presence there, especially at the greater distance from islands, cannot be attributed to decaying coral, and the difference in the amount of carbon dioxide in the ocean and lagoon respectively is so slight as to make it improbable that more solution of the reef-rock is taking place inside than outside the reef. In an enormous lagoon like that of Funafuti, where, especially at high tide, communication between ocean and lagoon is so extensive, one would hardly expect much difference in the carbon dioxide contents. But the fact that so much of this gas is present in the water of the ocean suggests that if it is a factor in the solution of the reef, then it must act on the ocean face as well as in the lagoon.

(C.) Experiments on the evolution of gases by coral. These were carried out on the suggestion of Professor T. W. EDGEWORTH DAVID, who had read Mr. GARDINER'S remarks on the subject in his paper on the coral reefs of Funafuti, Rotuma and Fiji.*

The determination of the evolution of gases by organisms of so low a development as corals is in itself a difficult task and one hardly to be attempted in places where it is a matter of impossibility to keep everything under the necessary control. So that results obtained in the field by makeshift apparatus can hardly be looked upon as conclusive in a matter of such great importance as the possible evolution by an animal organism of gases other than carbon dioxide.

This is what was done. An attempt was made to collect the gases, as they were given off, in bottles fixed over inverted funnels. The latter were fastened to boards, which, by means of legs, could be placed over coral. From the start the possibility of obtaining gas was considered very small. A coral, *Pocillopora verrucosa*, with its polyps fully extended, was watched in glass jars upwards of an hour at a time, during which not more than one or two of the minutest bubbles were seen to rise to the surface, and they might easily have been air bubbles which had adhered to the coral during its removal from the sea to the bottles. Further, the gases as they were evolved might be immediately dissolved by the surrounding water and hence not discoverable by the above method. The only sure one would be an analysis of the water before and after the corals were placed in it.

Then arose the difficulty of finding growing coral which was not closely associated

* 'Cambridge Phil. Soc. Proc.,' vol. 9 (1895–98), p. 483.

with seaweeds, either *Lithothamnion* or the green species, the presence of which rendered the results somewhat vague, since any gas collected might have arisen from either the coral or the plant. In all cases where the absence of seaweed was assured, as in that of coral placed in boxes, and some pieces growing on the sandy bottom of the lagoon, absolutely no gas was obtained, although the bottles were in position more than two weeks at a time. The only case in which gas was obtained was that of an Astræan coral which was growing on *Lithothamnion.**

(D.) Observations on the temperature of the sea water surrounding an atoll. The following few observations were taken at Onoatoa, in the Gilbert group, by means of a minimum thermometer kindly lent me by Mr. H. C. RUSSELL, F.R.S., during dredging operations about 1¼ miles off the shore, on November 25th, 1898.

Temperature of air at the time (10 o'clock a.m.), 86° Fahrenheit.

Surface water: 81° F.	At 60 fathoms, 80° F.
At 17 fathoms, 81° F.	At 90 fathoms, 72½° F.

* The glass flask in which this gas was collected was unfortunately broken during transit.

composed chiefly of detrital *Halimeda* with fragments of shells, intermixed with a little seaweed. Dredgings made elsewhere in the lagoon at depths not exceeding 12 fathoms showed that coral detritus (mixed with that of *Lithothamnion*) predominated in the sand-like material, giving place to *Halimeda* detritus, as already stated, at greater depths. Nowhere was any solid rock met with inside the lagoon except along the shore line or at the shoals and coral patches where the depth did not exceed a few fathoms.

As regards the dredgings outside the reef, we used ordinary iron dredges, a powerful and heavy toothed iron crown, kindly supplied by Professor HASWELL, sand pumps, a conical steel bucket and a chisel-edged drill, together with hemp tangles. The first two appliances could not be worked satisfactorily with the power at our disposal, the result of attempts to drag the dredges or the iron crown being that sooner or later the rowing boat became firmly anchored by them, and eventually these appliances and much rope were lost, though in the meantime they enabled us to secure a fair amount of useful material.

As regards the collections of specimens from the submarine slope of the atoll, we were most successful when working with a heavy steel chisel suspended by a strong but light rope. The chisel weighed about 80 lbs. and a tangle of hemp was attached to it in the manner represented on Plate 19. By alternately raising and dropping the chisel, by means of the rope, pieces were broken off *in situ* from the steep face of the reef, and some of them were arrested and retained by the tangles as fast as they were loosened by the chisel from the surface of the submarine slope. It was found possible to carry on this work successfully to a depth of 200 fathoms, but at that the task of hauling up by hand the heavy drill and tangles to the boat involved serious loss of time, and in rough weather was difficult to accomplish. A heavier drill would, we are sure, have been more successful, but the power available in a rowing boat is, of course, limited, and it is impossible for oarsmen to drag a heavy weight along a bottom like that of a reef face at depths of more than 200 fathoms. The two foremen, WELLS and HERBERT, brought from Sydney for the lagoon boring operations were invaluable here, as they were both sailors and good oarsmen, but the boat was heavy, the weather was hot and the work was hard and continuous, so that the progress often seemed slow and the results altogether disproportionate to the labour expended.

The conical steel bucket (Plate 19) when pulled up from a depth of 200 fathoms was frequently found to be full of sand-like material largely formed of comminuted fragments of coral about the size of peas together with foraminiferal shells and joints of *Halimeda*. Among the former *Cycloclypeus* was abundantly represented. We obtained both live and dead specimens of this type on the ocean side of the reef, at depths varying from 46 to 200 fathoms, but in the lagoon its shells were extremely scarce and no live specimens of this genus were observed. Similar sand and small fragments of coral were also obtained at depths, not exceeding 200 fathoms by some of us (Messrs. POOLE, WOOLNOUGH, and DAVID) off Pava and Fuafatu; at Pava calcareous

sand was fairly abundant at 40 fathoms. As regards the distribution of this sand and fine rubble generally on the submarine slope of the atoll, it would appear that it is absent for the most part from a little below low tide down to about 20 fathoms, wave action being probably sufficiently effective above this level to wash the fine detritus down from the upper part of the reef slope into the deeper water. A glance at the submarine contour of the atoll shows that at about 45 fathoms its submarine slope steepens suddenly from an angle of 25° or 30° up to 50°, 60°, or 70°, in places even becoming vertical. Hence the *Halimeda* zone is limited downwards to the depth of about 45 fathoms.* On this steep slope below 45 fathoms it might be thought impossible for any sand or fine rubble to lodge, but as a matter of fact we found that off Fuafatu the former occurred in small pockets even at depths of 70 fathoms, where the angle of slope was 70°. As living horny alcyonarian corals, belonging to the Gorgonidæ, were so abundant on this steep slope, between 40 and 100 fathoms, as to form a low scrub, it seems probable that they play an important part in arresting the sand and fine rubble in its downward progress. Numerous small projections likely to entrap rolling sand are also formed by lumps of living *Lithothamnion*, bristling with *Polytrema* and encrusted by tubes of *Serpulæ*, skeletons of Polyzoa, valves of small lamellibranchs, especially *Spondylus*, &c., as well as small solitary sea corals.

Here and there too, on this steep slope, loose flattish pieces of reef rock were found varying in size from a few inches up to 12 inches in diameter. Such fragments, entangled temporarily amongst the horny stems of the alcyonarians, would form traps for the foraminiferal and *Halimeda* sand descending from above. They would then, in common with the sand at their back, become overgrown by deep-sea organisms, particularly by the encrusting variety of *Lithothamnion*, until the whole of the fragmental material had been firmly cemented to the face of the submarine slope of the reef. Each fragment brought to the surface from these levels was a perfect curiosity shop of encrusting organisms. It was from such a one that Mr. HEDLEY obtained his specimen of the rare brachiopod *Thecidea maxilla*. He states in regard to it† : "This species was attached in considerable numbers, horizontally, perpendicularly, or obliquely to loose sheets of dead coral, which I pulled up by tangles in 40 to 80 fathoms on the western slope of Funafuti." Living specimens of the brachiopod *Crania* were also occasionally found off Falefatu and Tutanga at depths of 38 to 200 fathoms.

The fact that most of the loose fragments secured by us from the steep slope were flat in shape is, we think, significant. Such fragments would slip down slowly with an oscillatory or "butterfly" movement, like that of a coin sinking in water,

* This growth limit is no doubt chiefly due to the fact that being a green plant it cannot live below 45 fathoms, as the red and yellow solar rays which it needs for decomposing CO_2 and manufacturing chlorophyll are probably absorbed at depths greater than 45 fathoms, as FOL and SARAZIN have shown.

† Australian Museum, Sydney. Memoir III. Part 8, 1899, p. 509.

and so would be much more liable to be arrested in their downward progress by such a comparatively small obstacle as the horny stems of the Gorgonidæ, than would cubical and rounded fragments which would fall quickly to the base of the submarine cliff. As the nature and mode of origin of this submarine cliff, so characteristic of this as of many other atolls, appeared to us of extreme interest, we devoted more time to its study than to that of any other part of the submarine slope of the atoll.

Notwithstanding the small projections of *Lithothamnion* and the alcyonarian "scrub" above referred to, the general surface of the reef slope, between 45 and 140 fathoms, must be fairly smooth, as is proved by the fact that we repeatedly dragged our dredges over this part of the slope without their becoming foul, and we were even able to drag the big iron crown with its circle of teeth (each about 4 inches long) over the whole surface without its becoming entangled. This coral atoll accordingly affords us the remarkable feature of a nearly vertical wall 500 to 600 feet in depth, largely fragmental (at all events as regards its surface), which is being constantly added to, and which thus enlarges its periphery oceanwards, though at an extremely slow rate. We, of course, realised the importance of ascertaining what were the materials composing this cliff face, but as it was not practicable to moor a boat outside the atoll with a view of attempting to bore into this slope, we had to content ourselves with breaking off pieces by percussion with the heavy steel chisel, and recovering them simultaneously by means of the hemp tangles in the manner described above.

It may be mentioned that in the course of about two weeks' work in the aggregate, we never once obtained a specimen of what we might consider a piece of *ancient* coral reef rock. We had thought it possible, for example, that we might have secured fragments of some Tertiary rock like *Orbitoides* limestone or nummulitic limestone from the deeper levels, but nothing whatever of this nature was obtained. All the specimens collected by us were recent, mostly either a mass of partly living organisms or rolled fragments of reef rock slipped down from higher levels and cemented on to the steep face by *Lithothamnion*, *Polytrema*, *Serpulæ* and Polyzoa.

At the foot of the steep slope, at a depth of from 110 to 140 fathoms, our dredges frequently became foul. The material collected, whether with the sand bucket, or the sand pump, or the chisel and hemp tangles, was, however, very similar to that obtained from the steep cliff face. The same remark applies to our collections from still deeper levels, down to over 300 fathoms. As already stated a good deal of sand was found at or near the 200-fathom level.

On the whole the results of our dredging between 140 and 200 fathoms appeared to supply evidence not inconsistent with the view already expressed by Professor SOLLAS, that the convex outward curve in the contour of the atoll (as seen in section) for a short distance below the base of the submarine cliff, is due to an accumulation of fragmental material fallen over the cliff, and now forming a talus at its base.*

* 'Nature,' vol. 55, February, 1897, p. 375.

Of the encrusting types of foraminifera, *Polytrema planum* and *P. miniaceum* are abundant, as well as several species of *Carpenteria*. *Polytrema planum* in particular is quite an important rock builder on the ocean submarine slope of the atoll, as described by Mr. F. CHAPMAN.*

Mr. CHAPMAN† aptly compares the large white flaky masses of *Polytrema planum*, many specimens of which we dredged from the ocean slope, to the nest of the wasp (*Vespa*). Much of the frothy white material (like spongy plaster-of-paris), which plays such an important part in cementing the sand and fine rubble on the ocean slope of the reef down to at least 200 fathoms, has now been proved by Mr. CHAPMAN to be *Polytrema planum*. At the time we dredged it we mistook it for dead *Lithothamnion*. A certain amount of living *Lithothamnion* was in most cases associated with it.

In addition to the *Cycloclypeus*, another organism of bathymetric value is the pteropod. This was sufficiently abundant to form a deposit almost amounting to a pteropod ooze at a depth of about 200 fathoms, and occurred in some abundance at a rather less depth, being met with in our dredgings from depths of 80 fathoms down to 200 fathoms.‡ In this case also it might be argued that an absence of pteropod shells from the core at a depth as great as 186 fathoms (the maximum depth attained by the bore) argues subsidence. With a stationary or rising floor it must be assumed that, if the reef rock of the core was formed on the ocean side of the atoll, the pteropods were never able to occupy this in numbers sufficient to produce pteropod ooze, and if on the lagoon side, that this part of it had originally the extraordinary depth of 186 fathoms, both of which are very improbable hypotheses.

(2) As regards the distribution of *Lithothamnion*, while on the western side of the atoll branching and knobby varieties are extremely abundant in the shallow water from the level of low-water spring tide to a few feet below that level, the encrusting type of *Lithothamnion*, which is of universal distribution around the ocean face of the atoll, lives from low-water spring tides down to at least 200 fathoms. As already stated, it is the great cementing agent which binds together into a compact rock the sand and rubble of the ocean slope of the reef as well as that of the shores of the lagoon below low water. Its red colouring matter (phycoerythrin ?), as FOL and SARASIN and others have shown, no doubt enables it to live at depths too great for the red or yellow rays of the solar spectrum to penetrate, and far below the zone of green plants, like *Halimeda*. Although this encrusting *Lithothamnion* is a slow grower, still it would be hard to over-estimate its importance as a former of reef rock. The question here suggests itself, is there any evidence derived from an examination of the *Lithothamnion* of the submarine cliff which would enable

depth than 30 fathoms, the same species was found off the Tonga Island at 20 fathoms, and on a piece of the reef coral *Turbinaria* from the Mauritius a specimen was found, which presumably lived at the same depth as the coral."—ED.]

* 'Linnean Soc. Journ.,' Zoology, vol. 28 (1900–03), pp. 387–396.

† *Ibid.*, p. 391.

‡ Australian Museum, Sydney. Memoir III. "The Atoll of Funafuti." By C. HEDLEY, p. 549.

Halimeda alive from a depth of 40 fathoms off Funamanu, on the south-east side of the atoll. Sand composed of joints of *Halimeda* was collected by us in more or less abundance in all our dredgings, off Pava, Fuafatu, Tebuka, Tutanga and Funamanu. Mr. FINCKH considers the downward limit of *Halimeda* at Funafuti to be about 45 fathoms. He records a single instance of it being brought up alive in the tangles from a depth of 86 fathoms. This was off Tutanga. It may be mentioned, however, that during the dredging done at Funafuti in 1897, *Halimeda* was never found alive much below 40 fathoms. In view, therefore, of the strong evidence in favour of a downward limit for its growth of about 45 fathoms, we are inclined to believe that the specimen dredged from 86 fathoms was probably not *in situ*.

If the distribution of *Halimeda* at Funafuti be briefly summarised, it may be stated that this alga lives from a foot or so above low-water spring tide down to about 45 fathoms below sea-level. It grows luxuriantly and rapidly, chiefly in the sandy floor of the lagoon (which Mr. HALLIGAN'S bore proves to be covered, to a depth of at least 80 feet, chiefly with sand composed of joints of *Halimeda*), and on the sandy submarine slope of the atoll on the ocean side just above the top of the submarine cliff. In fact the *Halimeda* forms a continuous green belt on the outer slope of the atoll between depths of 20 and 45 fathoms.

(4) *Corals.* In the earlier part of this Memoir, Mr. A. E. FINCKH has already recorded his personal observations on the distribution of the corals at the shallower levels. Mr. J. STANLEY GARDINER has given detailed descriptions of such corals,* as has also Mr. T. WHITELEGGE of the Australian Museum, Sydney.† Here then we shall give only a brief summary of the results of our dredgings in the deeper water, chiefly from a depth of about 20 fathoms down to 200 fathoms. Most of our dredging was done on the western side of the atoll, and here we found that *Madrepora loripes*, which is described by one of us (A. E. FINCKH) as being very abundant and characteristic of this part of the atoll, occurred alive, off Funafuti Island, down to depths of about 10 to 15 fathoms.

With regard to *Heliopora cærulea*, which forms such extensive living masses in the Funafuti lagoon, in its northern, southern and western portions, it is singular that we did not obtain a single living specimen of it in our deeper dredgings from 20 to 200 fathoms. Careful examinations by one of us (A. E. FINCKH) with a water telescope off Fuamanu, Falefatu and Funafuti main island, opposite the diamond-drill camp, failed to reveal the presence of any living *Heliopora cærulea* on the submarine slope of the atoll facing the ocean.

Mr. GARDINER, as stated above, records having dredged one small piece of

* 'Proc. Zool. Soc.,' London, 1898, pp. 257–276, Plates 23 and 24; pp. 525–539, Plates 43–45, and pp. 994–1000, Plate 62. A report on the Gorgonacean Corals, collected by Mr. GARDINER, by ISA L. HILES, B.Sc., is given, *ibid.*, 1899, pp. 46–54, Plates 1–4.

† Australian Museum, Sydney. Memoir III, pp. 211 and 305. Plates 16–18 (Alcyonaria), and p. 347 (Madreporaria).

SECTION VIII.

REPORT OF LAGOON BORINGS.

By G. H. HALLIGAN.

IN the early part of the year 1898, Professor T. W. EDGEWORTH DAVID mentioned to me some of the difficulties which he encountered when trying to sink a bore in the lagoon at Funafuti, and deplored the waste of time and energy in the unsuccessful venture.

As I had been for some years in charge of all borings in connection with harbour and bridge works in New South Wales, a large part of them being carried out from floating pontoons, and under circumstances somewhat similar to the work required to be done at Funafuti, I suggested that the gear found so useful here might be efficacious there. Borings had already been carried out without difficulty to a depth of 184 feet through mud, sand, clay, and hard shale, from a punt moored in 88 feet of water in the harbour of Port Jackson, and as the chart showed 17 to 18 fathoms at the site of the proposed lagoon boring at Funafuti, the difficulties did not appear to be insuperable. On the matter being mentioned to Mr. C. W. DARLEY, M. Inst. C.E., Engineer-in-Chief for Public Works, under whose control are all matters in connection with these borings, he at once gave the proposal his warm support, and on receipt of an application from Professor DAVID and Professor ANDERSON STUART, the Government generously granted the proposed expedition the use of all necessary gear and machinery, and approved of my leave of absence for about three months to conduct the operations. Plans were prepared of punts to be built in sections at the Fitzroy Dockyards in Sydney, and to be conveyed to Funafuti, but almost at the last moment it was found that the funds available were not sufficient to pay the freight on such bulky goods. The most strenuous efforts were made to obtain subscriptions, but they were unsuccessful, and the lagoon-boring seemed as though it would have to be abandoned. However, on the representation of Professor DAVID and Professor ANDERSON STUART, the Admiralty kindly granted the use of H.M.S. "Porpoise," in charge of Commander F. C. D. STURDEE, for this experiment. The punts, though built in sections, were found to be too bulky to convey to Funafuti on the crowded deck of a war-ship, so it was decided to try to carry out the borings from the bow of the ship.

As the men on H.M.S. "Porpoise" were quite inexperienced at the work, and the time at our disposal was limited, it was decided to continue the boring night and day,

and two experienced foremen from the Public Works Department, Messrs. A. WELLS and J. HERBERT, were selected in Sydney to assist me. We journeyed from Sydney to Suva, in Fiji, in the s.s. "Ovalau," arriving on the 8th of August, and after transferring our gear and luggage to H.M.S. "Porpoise" we started for Funafuti on the 10th at 1 P.M., arriving at the atoll on the 13th at daylight.

The ship was moored in the position indicated on the chart without any difficulty, and the staging rigged and everything made ready on the 13th and 14th, and we started lowering the boring tubes on the 15th of August at 6 A.M., in 101 feet of water at low-water spring tides. The illustration showing the method adopted of

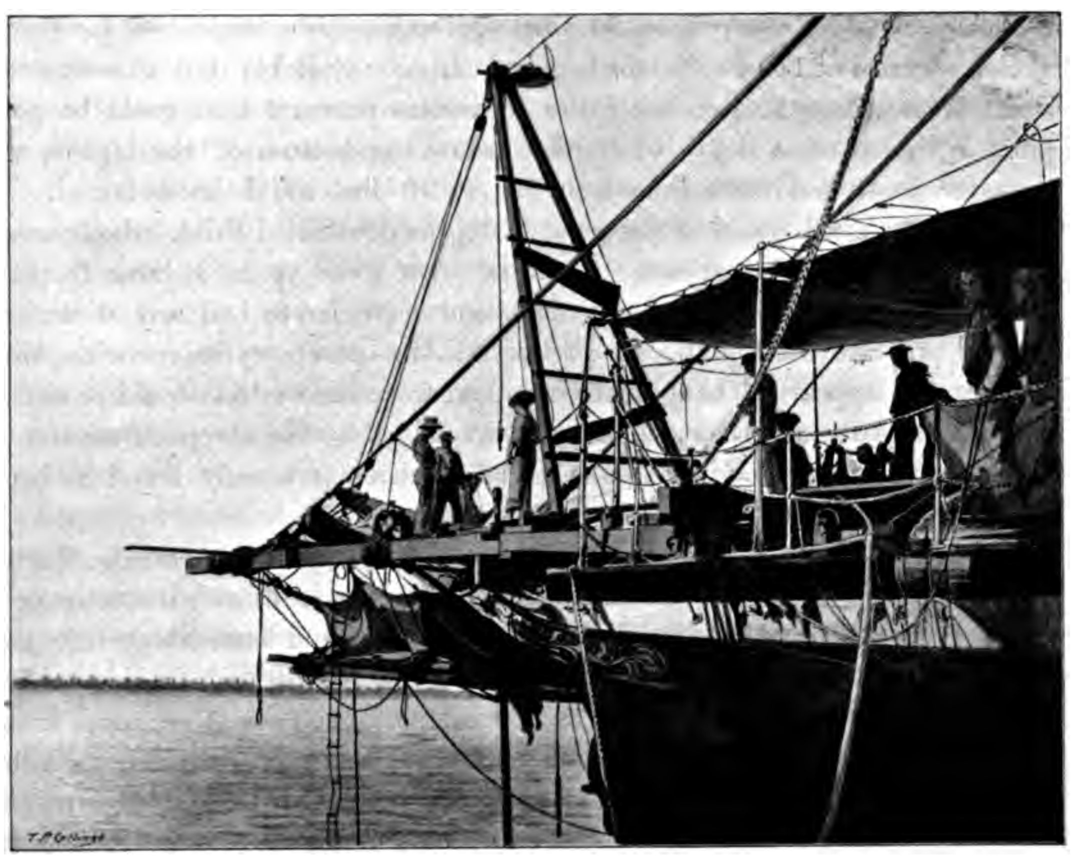


Fig. 20.—Boring apparatus on H.M.S. "Porpoise."

working the boring gear from the bow of the ship, is from a photograph by Lieut. GAUNT, R.N., one which I took having been destroyed. The confined space we had at our disposal and the inconvenience of working from a hanging stage, was against making rapid progress, and had it not been for the ready help afforded by the officers and men of the ship it would have been impossible under the circumstances to have carried out the work at all.

Four-inch wrought-iron artesian well tubing was used, having an inside diameter of $3\frac{5}{8}$ inches, this size having been found capable of withstanding considerable

hammering in 88 to 90 feet of water in Sydney Harbour and other places, while its weight—about 10 lbs. to the foot—is not of much moment in borings of less than 500 feet depth. When the tube had been lowered to the floor of the lagoon, and a sample of the bottom obtained by the aid of a sand-pump, a flexible rubber hose, connected with a 6-in. by 4-in. by 6-in. Worthington steam pump, was attached and water pumped down to scour away the mud, sand, or shells, and thus allow the tube to sink. Additional tubes were of course screwed on as the work progressed, and samples of the strata passed through obtained at intervals, by the tools designed for the purpose. The tools used were of a simple character. In this, as in all other boring work, success depends more on their intelligent handling than on the tools themselves.

A boiler pressure of 110 lbs. to the square inch was available, but this was never required; from 40 to 80 lbs. being the maximum pressure that could be got on the pump cylinders at a depth of 80 feet below the bottom of the lagoon, while at a greater depth not more than from 20 to 40 lbs. could be obtained. The coarseness of the coral gravel at the greater depths does not I think wholly account for this, for during my experience extending over some years I have frequently had to sink through much coarser gravel, and have never had any difficulty in obtaining a pressure of from 60 to 80 lbs. on the pump cylinders with similar gear. It would appear as though the ocean had freer access than could be obtained through the coarsest gravel, but this may be explained by the absence from the coral sand and gravel of any mud or fine material, such as is usually found in borings in river or harbour beds.

A depth of 182½ feet was reached at 5.35 P.M. on the day of the starting, the tubes passing for the whole of this distance through *Halimeda* sand with more or less fragmentary specimens of shells of marine gastropods and lamellibranchs. Fairly numerous blackened remains of plants were observed at intervals in this sand, the last five feet of which was so coherent as to necessitate the use of an auger in order to penetrate it. At this depth a hard mass of coral was met with, having a thickness of 18 inches, and requiring the use of a heavy steel percussion drill to pierce it. The weight of the tubes was sufficient to enable us, by alternately raising them and letting them fall, to fracture this obstacle, which was either a loose slab of coral of immense size or coral rock *in situ*. Experience generally enables a borer to tell, from the ring of the boring tool, the difference between solid rock and a boulder, unless the latter is very large. In the present case the ring indicated solid rock, and the occurrence of a similar mass at a depth of 193 to 196 feet in the second boring, which will be referred to later on, certainly suggests rock *in situ*.

Below this coral mass we encountered a stratum of coral gravel and sand which extended to a depth of 217 feet. The fragments of this coral gravel varied in size from that of a pear to that of a walnut, pieces as large as a small hen's egg being occasionally met with. They were mostly subangular, and quite unlike the well-rolled

ship caused such sudden strains on the hoisting gear that nothing at my command would stand. It was therefore decided to unscrew the pipes near the bottom of the lagoon, and the ship's diver was sent down to insure that no faulty joint would cause the pipes to unscrew above the navigation level, say 30 feet. Fortunately the weakest joint in the pipe was found to exist 34 feet from the lower end, so that amount of tubing represents the total loss caused by our not being able to draw it in the usual way.

We started to sink No. 2 bore in 101½ feet of water at 3.30 P.M. on the 19th August, and found *Halimeda* sand with fragmentary shells, similar to that described in No 1 bore, to 193 feet. At this depth hard coral was met with having soft bands, an inch or two wide, at from 4 to 6 inches intervals. This formation extended to 196 feet, when we encountered coral gravel and sand very similar, as the specimens will show, to that described in bore No. 1. The coral rock or boulder was too solid to break with the appliances I had, and the same difficulties of under-reaming presenting themselves, as previously described, it was decided to abandon the attempt to sink a bore in the lagoon with the appliances then on hand. So at 10 A.M. on the 20th August we started to pull the tubes up, and at 1.30 P.M. all the gear was stowed away, and I reluctantly turned my attention to other matters.

It is perhaps only fair to mention that the lagoon borings here described were undertaken without the least idea of the formation to be expected, and were carried out under the most unfavourable circumstances possible. On account of the limited funds available, appliances and tools suitable for all contingencies could not have been provided, and the limited time at our disposal and the small space available on the warship would not allow of different sizes of tubes being used. Added to this the inconvenience of working from the bow of a ship already crowded with necessary gear, and the total inexperience of the men at this particular class of work, it will be at once apparent that, had it not been for the co-operation and energy of the captain, officers and men of H.M.S. "Porpoise," the work could not have been carried out at all. In connection with this I would like to mention the kindly help and valuable advice I received from Mr. A. E. TOMKINS, Chief Engineer, who went to a large amount of trouble, under exceptionally trying circumstances, to assist the work.

SECTION IX.

PERMANENT REFERENCE MARKS ON THE ISLAND OF FUNAFUTI.

By G. H. HALLIGAN.

IN order that permanent marks should be available for future reference, both as to level and to the contour marks of high and low water on the ocean and lagoon sides of the main island of Funafuti, some iron pipes were let into the coral rock in the positions shown. (See Plate 19.) These pipes were 4 inches outside diameter and from $3\frac{1}{2}$ to 4 feet in length. They are sunk to a depth of from 2 to $2\frac{1}{2}$ feet into the solid rock of the reef platform, are firmly secured with Portland cement and filled with the same material, and each mark stands 15 inches above the surface, so that they can be seen from a considerable distance. On my arrival at the atoll I found that Mr. FINCKH had already sunk copper plugs in the positions shown on the plan, but as these stood only about 1 inch above the surface of the coral, they were difficult to find, though perhaps they were less liable to injury on a storm-swept coast than the marks I have now left. In order to indicate the positions of these plugs more clearly to future visitors, we decided to sink three of the cement-filled pipes alongside them, and as the pipes would be exposed to the full fury of the storms which break off the masses of coral from the outer edge of the reef and hurl them shorewards to form the Hurricane Bank, it was thought desirable to place another mark at about high water, the exact position of which is shown on the plan referred to. The top of this mark (A on the plan) is 7·60 feet above the zero of the tide gauge used on the survey of the atoll, made by Captain MOSTYN FIELD, R.N., of H.M.S. "Penguin," in 1896, and is 5·98 feet below the bench mark on the south-west corner of the Mission Church. According to information kindly supplied by Admiral Sir W. J. L. WHARTON, Hydrographer to the Admiralty, the mean tide level, as deduced from the two months' observations made during this survey, is 3·38 feet above the zero of the gauge. The mark A may then be taken to be 4·22 feet above this mean tide level and approximately the same height above mean sea level. For measurements of any considerable movements in elevation or subsidence this mark may be of value, but, of course, a series of observations extending over a much longer time would be required before mean sea-level could be determined with sufficient accuracy to admit of minute measurements. The two pipes forming the permanent marks on the lagoon side of the islet are in the vicinity of the northern end of the "Sandy Beach," shown on the Admiralty chart, about

490 metres northerly from the Mission Church. They are of the same dimensions, are secured in the same way, and are filled with pure Portland cement in the same manner as the pipes on the ocean beach. As shown on the plan (Plate 19), one of these pipes is close to high water and the other near low water. The top of the one nearer to high water is ·08 foot below the mean tide level referred to above, with a limit of error of plus or minus ·005 foot. Diagram A (Plate 19) shows the relative positions of the copper plugs and the cement-filled pipes on the ocean platform. Copper plugs were not placed on the lagoon platform.

SECTION X.

GENERAL REPORT ON THE MATERIALS SENT FROM FUNAFUTI, AND THE METHODS OF DEALING WITH THEM.

By Professor J. W. JUDD, *C.B., LL.D., F.R.S.*

HAVING been entrusted by the Coral Reef Committee of the Royal Society with the examination of the cores and other materials obtained during the several expeditions to Funafuti in 1896, 1897, and 1898, I proceeded, with the sanction of the Board of Education, to make such arrangements as were possible for carrying on the work in the Geological Research Laboratories of the Royal College of Science at South Kensington. Owing to the large mass of materials sent on from Sydney, consequent upon the success attending the last year of the work, the task proved to be a much heavier one than was originally anticipated, and a corresponding delay has occurred in completing it.

In the execution of the work during the last six years, I have received much valuable assistance from my colleagues, Mr. F. CHAPMAN (now of the University Museum, Melbourne), Dr. C. G. CULLIS, and Dr. E. W. SKEATS; while very useful chemical work has been done in connection with the inquiry by Mr. J. HART SMITH, under the supervision and in the laboratory of Professor TILDEN. During visits which they have paid to this country, Professor T. EDGEWORTH DAVID and Mr. G. SWEET have afforded me much assistance, while Dr. SORBY, Professor SOLLAS and Mr. STANLEY GARDINER, with Sir JOHN MURRAY and Professor ALEXANDER AGASSIZ, have from time to time given me very valuable counsel and aid. To the officers of the Natural History Division of the British Museum—Professor E. RAY LANKESTER, Mr. G. MURRAY, Professor T. JEFFREY BELL, Mr. KIRKPATRICK, Mr. BERNARD, and others—I have always been able to appeal in cases of doubt or difficulty.

But it is to Dr. G. J. HINDE that I especially owe a deep debt of gratitude for his most invaluable assistance. He has devoted many months of patient labour to the study of the various cores, and of the sections prepared from them, directing his well-known skill in this kind of research to the elucidation of the nature of the organisms, the skeletons of which had often undergone great alteration by chemical action. But for Dr. HINDE's invaluable aid, it may be safely asserted that it would have been

impossible to have obtained the full and important results from the materials collected with so much labour and expense at Funafuti.*

The collections obtained by Professor SOLLAS during his stay in Funafuti in 1896 were handed to me immediately upon his return, and though the two borings he made only reached to depths of 105 feet and 72 feet respectively, yet their study proved to be a most valuable preparation for the work to be done on the larger collections sent to England in subsequent years. Besides the cores from the two borings—which consisted for the most part of rubbly fragments mingled with disintegrated sand-like material—valuable collections of the surface rocks and of the beach-sands of the islets, with corals and other organisms from different parts of the atoll, were entrusted to me; and these have afforded a basis of study for the materials which were, later, obtained at considerable depths. Some of the phosphatised materials collected on the islands by Professor SOLLAS have proved, as will be shown in the sequel, to be of great interest.

The first collections made by Professor DAVID and Mr. SWEET during their sojourn in Funafuti in 1897 reached me in March, 1898, having been forwarded from Sydney in eleven core-boxes, each 12 feet long, by the s.s. "Orizaba." The cores from the main boring, which, at the time of their despatch, had attained a depth of 698 feet, were in a most satisfactory condition for study, each core was numbered, its position in the bore-hole being indicated by a black line drawn round its *lower end*, while its depth from the surface and other particulars were recorded in an accompanying catalogue. The same care in collecting and recording was manifest in all the subsequent consignments.

In January, 1899, the second portion of the core, that obtained by Mr. FINCKH in 1898, reached the Royal College of Science, South Kensington. It was contained in six core-boxes, which were brought by the s.s. "India," and contained the cores from 698 to 987 feet.

In April, 1899, the third and final portion of the core, from 987 to 1114½ feet, reached this country by the s.s. "Britannia," being contained in five core-boxes. The solid cores in the first consignment were numbered from 1 to 366, while those in the second and third consignments were numbered from 1A to 709A.

There were also sent from Sydney the valuable collection of specimens made in a series of dredgings across the lagoon of Funafuti, with the materials brought up in the two borings in the lagoon, so successfully put down by Mr. HALLIGAN, the deepest of which reached 245 feet from the surface of the water. These borings were made, as already described,† from the deck of H.M.S. "Porpoise," under Commander STURDEE, R.N.; the materials obtained proved scarcely less important, in the information they afford concerning the constitution of the coral reef, than the cores brought up from the main boring.

* See Section XI.

† See Section VIII

In addition to these, very numerous specimens of sand and rock from all parts of the atoll, with the specimens obtained by the dredgings on the outer flanks of the atoll down to 200 fathoms, were entrusted to me by Professor DAVID, Mr. HALLIGAN, and Mr. FINCKH, together with illustrations of the rate of growth of the various reef-forming organisms described in a previous report (p. 141). Captain A. MOSTYN FIELD, through the Hydrographer to the Admiralty, Sir W. J. L. WHARTON, sent to me the materials brought up in the deep-sea soundings around the Ellice Islands.

I may now proceed to describe the manner in which these various materials have been dealt with.

A. *The Materials from the Main Boring,* $1114\frac{1}{2}$ *feet.*

Thanks to the experience gained in the first attempts during the pioneer expedition under Professor SOLLAS, to the great skill and resourcefulness displayed by Professor DAVID, and to the professional ability of the workmen brought from Sydney, this boring was carried to a very satisfactory depth—a depth which, considering the difficulties that had to be overcome, must be regarded as surpassing the most sanguine expectation of those who projected the expedition. The boring was commenced with a diameter of 5 inches, but, when a depth of 68 feet had been reached, this had to be reduced to 4 inches, while, at a depth of 210 feet, a further reduction to $3\frac{1}{8}$ inches became necessary. In spite of these reductions, however, the boring was carried to a depth of $1114\frac{1}{2}$ feet, the upper 700 feet being fitted with lining tubes, while, below that depth, the solidity of the rock permitted of lining tubes being dispensed with.

The first part of the boring, 68 feet long, like the cores sent home by Professor SOLLAS, yielded only a number of fragments of solid rock, the united lengths of which amount to less than 17 feet. The next 142 feet of $3\frac{1}{4}$-inch core included solid pieces also, with a united length of 17 feet only. In the succeeding 163 feet of boring (that is, from 210 to 373 feet), very little but disintegrated material was brought up, the few solid fragments in this part of the boring having a united length of 14 inches only! For 264 feet more (from 373 to 637 feet) the disintegrated material was much in excess of the solid core, there being only 18 feet of solid rock in the whole of this distance. But, between the depths of 637 and 748 feet, a remarkable change was manifest in the character of the material. The rock became soft and earthy in character, almost resembling chalk in outward appearance, the separate organisms also becoming less conspicuous. A careful examination, however, showed this resemblance to chalk to be merely superficial, for, with a lens, all the plants, foraminifera, and corals occurring in the higher portions of the core were found to be present, and this conclusion, as will be seen in the sequel, has been entirely confirmed by the microscopic study of thin sections.* Although fairly

* See Dr. HINDE'S Report, Section XI.

compact, the rock in this part of the core was soft, and in some places very porous, so that much of it broke up under the boring tools, and, in the 111 feet of boring, only 19 feet 6 inches of solid core was yielded. At the depth of 748 feet another change took place, and the rock became very hard and compact in character, but with occasional reversions to the softer type. From this point to the lowest depth reached in the boring, a distance of 366½ feet, the rock was so hard and solid that no less than 312 feet of core was brought up, the loss which occurred being evidently largely due to the grinding one on another of the broken fragments of core. Many of the cores from this part of the boring were a foot or more in length; one (523A), from a depth of a little over 1000 feet, reaching a length of nearly 2½ feet, while a second (678A), from nearly 1100 feet, was over 3 feet in length.

The disintegrated sandy-looking material, so abundant in the upper portions of the boring, was seen by the aid of the lens to be neither waterworn nor windworn. On the contrary, it was found to be made up of angular fragments consisting of foraminifera and other organisms, whole or fragmentary, evidently broken out of a loosely-cemented mass. It became clear upon closer examination that the reef rock in this part had become loose and cavernous through the removal by solution of the corals and other organisms composed of aragonite, and that the mass, thus weakened and rendered porous, not being able to withstand the action of the boring tools, had been reduced to a mass of disintegrated particles. The few solid fragments brought up consisted almost entirely of more or less perfectly preserved calcite organisms.

In the core-boxes, as sent from Sydney, the disintegrated material washed up from the boring was packed in its proper place between the pieces of core, but as there was some risk of admixture (there being two or three rows of core in each box, only separated by loose laths), we were supplied by Professor DAVID with boxes of "sand" carefully collected at every few feet of depth. These "sands" were sifted and had their organisms, which were chiefly foraminifera, carefully picked out and studied.

As it was agreed that the cores obtained from this important boring should be equally divided between the Sydney Museum and the British Museum, I determined to slit each solid core longitudinally, cutting out from the centre any slice or slices which might be necessary for microscopical or chemical examination. In the higher portions of the boring, where the proportion of solid core was small, this task was a comparatively easy one; but when, as was the case in the lowest 400 feet, the core was found to be almost continuous, the labour involved became very great. Attempts were made to get this work done more expeditiously by marble merchants, but the results were not satisfactory and, in the end, it was resolved to avoid all risks by completing the cutting up of the cores in the laboratory at South Kensington. This was, however, greatly facilitated by using a lapidary's wheel driven by an electro-motor, which was set up at my request by the Board of Education. Some part of the delay in bringing the task to an end is, of course, due to the fact that all research work in a college has to be subordinated to the regular teaching.

At the depth of 637 feet the white chalky-looking rock gave such indications of having undergone great chemical change, that I tested for magnesia and found it to be present in large quantities. In view of the important observations made by the late Professor J. D. DANA in 1843 and subsequently in many of his writings* on the dolomitisation of coral reefs, I determined to make a complete examination of the chemical composition of the whole ot the materials from the borings at Funafuti. Two of my assistants, Dr. C. G. CULLIS and Dr. E. W. SKEATS, could fortunately be spared for a time to undertake portions of the work, while the remainder of the chemical work was done in the Chemical Laboratory of the Royal College of Science by Mr. J. HART SMITH under the superintendence of Professor TILDEN, the expenses of this part of the work being defrayed by a grant from the Royal Society. The results of this chemical work and a discussion of them are given in a separate report.†

In order to determine the nature of the organisms in the solid cores it was proposed, in the first instance, to make a thin slice of the whole size of each core, cut out of its middle. It was found, however, to be very difficult to make such large slices sufficiently thin for the purpose of exact study, while it would have been necessary to submit each of these sections in succession to specialists who would study every group of organisms that might be represented in them. This method was, therefore, abandoned for another when a depth of about 200 feet was reached. It was found that the slice cut from the middle of the core afforded a good indication of the general composition of the core, and that doubtful or difficult points could be settled by having very thin sections made from that portion of the slice in which the difficulty presented itself. When a depth of 800 feet was reached it was found that the surfaces presented by the hard cores, when slit by the lapidary's wheel, were sufficiently well polished to indicate the general nature of the organisms, and in consequence the labour of making the double cut through the core was avoided; small thin sections were, however, prepared whenever the study of the polished core surfaces showed such to be desirable.

The examination of the cores from the depth of 637 feet to the bottom indicated that the materials had undergone the most extensive chemical and mineralogical changes. It was evident that not only portions of or the whole substance of organisms had been removed in solution, after their interstices had been filled with calcareous mud, but that recrystallisation and dolomitisation had gone on to a considerable extent. In the lower and more crystalline portions of the core, the corals, with some of the mollusca and other organisms, only existed in the form of casts, while secondary crystalline deposits had evidently been formed in the cavernous

* See 'Amer. Journ. Sci.,' vol. 45 (1843), p. 120; *ibid.*, vol. 47 (1844), p. 135. "United States Exploring Expedition (Zoophytes)," 1846, p. 712 Compare also the successive editions of 'DANA'S Manual of Geology.'

† Section XIV.

mass, rendering it more or less solid and compact. Although no trace could be found of anything but existing organisms, it was evident that the remains of these had undergone such great chemical and mineralogical changes that they would have to be studied like fossils, especially by the aid of thin sections, and that the ordinary methods of diagnosis of the zoologist were of little avail.

Under these circumstances it was very fortunate that I was able to induce Dr. G. J. HINDE to give his invaluable aid in determining the organisms contained in the core. With the exception of the foraminifera, which were determined by my assistant Mr. F. CHAPMAN, all the other organisms were diagnosed by Dr. G. J. HINDE, with the advice, where necessary, of the zoologists and botanists of the British Museum.

As a preparation for the work, specimens of the various genera of corals represented in the core (generally obtained from Funafuti) were selected as types, and from these longitudinal and transverse sections, with occasional oblique sections, were cut. As casts were of such frequent occurrence in the lower cores, wax-impressions of all the forms were also taken, wherever found necessary. In this way a good series of types for comparison were obtained for the corals, while the numerous collections made on and around the islets of the atoll supplied the means for equally exact comparison in the case of other classes of organisms.

The cut faces of the cores and the slices taken from them offered sufficiently polished surfaces for a general determination of the organisms present in them, all difficult cases being met by preparing thin transparent sections from selected portions. In the course of the work over 500 thin microscopic sections were cut and studied, and these are preserved together with the half-cores in the British Museum.

In his notes on the cores, Dr. HINDE has remarked upon the general mode of preservation of the organisms and the more or less crystalline character of the material in which they are embedded. A selection from the series of thin sections was submitted to Dr. H. C. SORBY, who has kindly furnished a general report on the subject of the chemical and mineralogical changes which coral-reef rocks undergo.*

The more detailed study of the mineralogical changes taking place in the cores has been carried on by Dr. C. G. CULLIS, following the lines laid down by Dr. SORBY in his Presidential Address to the Geological Society in 1879. The work has, however, been greatly facilitated by the employment of more recently discovered micro-chemical methods—namely, MEIGEN'S test for discriminating between calcite and aragonite, and LEMBERG'S test for distinguishing calcite from dolomite. In arranging for the best methods of applying these valuable tests, we have received much assistance from the officers of the Geological Survey and of the Mineralogical Department of the Natural History Museum, our special thanks being due to Mr. TEALL and Dr. POLLARD, and to Mr. L. J. SPENCER.

The whole of the thin sections examined in the first instance by Dr. HINDE and

* Section XIII.

algal growths, have not hitherto attracted the attention which they deserve. There is evidence that they abound in many coral-reef deposits in all parts of the world.

The question of the existence of anything like stratification in the materials building up the reef rock was one to which special direction was directed. Professor DAVID, whose notes on the specimens were of great service to us, called attention to several cores, on the outside of which obscure markings suggesting stratification, usually with a very steep dip, were noticed by him. These cores were carefully cut *at right angles* to the supposed dipping laminæ, and in all cases the appearances proved to be fallacious. The numbers of the cores in which something like stratification was suspected were 61A, 67A, 89A, 125A, 178A, 194A, 321A, 327A, 328A. The description of these cores, by Dr. HINDE, will be found in his report, and the numbers of all cores in which stratification was suspected is given, so that our remarks upon them can be verified in either the British Museum or the Sydney Museum halves of the cores. The conclusion at which we arrived was that nowhere could a stratification, such as might be expected in a talus-formation, be found, but only such irregular accumulation of detrital materials as takes place between and around the corals; and these appearances were presented at many points, from the top to the bottom of the bore-hole, whenever consolidated rock could be examined.

Another point on which very careful observations were made, was with a view to determine if anything like an admixture of deeper-water organisms could be detected among those building up the reef. The numerous dredgings made by Professor DAVID, with the aid of Messrs. FINCKH and HALLIGAN, enable us to understand the nature of the flora and fauna of the ocean-face of the reef down to 200 fathoms, while the deep-sea soundings made by Captain FIELD, in H.M.S. "Penguin," supply information as to the organisms living at still greater depths. Now, had any portion of the rock of the core consisted of material fallen from above, and resting at lower points on the ocean-slope, we should expect to find an admixture of these shallow-water forms that had fallen with others belonging to a greater depth which had grown on and around the fallen fragments. But distinct as are many of the forms of life which occur living on the ocean-face of the reef between 100 and 200 fathoms, not a trace of these was found in the lower portions of the Funafuti core. Dr. HINDE's carefully drawn-up lists show that from top to bottom the same organisms occur, sometimes plants, sometimes foraminifera, and sometimes corals predominating; but in the whole depth bored the same genera and species of these various groups of organisms take their part in the building up of the mass.

As the rocks through a large portion of the bore-hole showed such striking evidence of having undergone great chemical and mineralogical changes, the question of the possible existence of older Tertiary limestones forming the basis on which a modern reef had grown up, became one which it was evidently necessary to keep in mind. The circumstance that both in the Indian and Pacific Oceans coral reefs founded on old Tertiary limestones are known to exist, made investigation of this point very desirable.

It fortunately happened that the large collections made at Christmas Island, in the Indian Ocean, by Dr. C. W. ANDREWS, for Sir JOHN MURRAY, were available for comparison, and among these the Tertiary limestones are well represented.* In the same way, we are indebted to Professor ALEXANDER AGASSIZ for supplying us with a series of specimens collected by himself, or under his direction, by Mr. E. C. ANDREWS, of Sydney,† and these specimens, derived like those of Christmas Island, in the Indian Ocean, from upraised reefs in different parts of the Pacific, include a number of examples of the old Tertiary-limestone platforms on which modern coral reefs have, in some cases, been built up.

While the study of the Funafuti collections has been in progress, I have been able, through the liberality of Sir JOHN MURRAY and Professor AGASSIZ, as well as of Professor DAVID, in supplying me with specimens, to make constant comparisons of the Funafuti rocks with those of the upraised reefs of the Indian and Pacific Oceans. My assistants, Dr. E. W. SKEATS and Mr. R. L. SHERLOCK, have prepared memoirs on the chemical and microscopical character, and on the organisms of the rocks of these upraised coral islands, and Professor AGASSIZ has been good enough to publish these memoirs in the same journal as that in which the account of his own researches will appear.

It was found by Dr. SKEATS and Mr. SHERLOCK, and also by Mr. F. CHAPMAN, who assisted them in the palæontological portion of their work, that, even in very small fragments of rock, the characteristic Tertiary organisms, such as the various species of *Orbitoides*, could be detected in their microscopic sections. Such Tertiary organisms were found in limestones from Christmas Island, in the Indian Ocean, and also in limestones from Mango and Namuka, in the Fiji group of the Pacific Ocean.

But although nearly 400 feet of core from the bottom of the Funafuti core were very carefully scrutinised by both Mr. F. CHAPMAN and Dr. HINDE for the purpose, not a trace of these Tertiary organisms could be detected. On the contrary, as the reports show, the same recent forms of foraminifera, corals and other organisms occur from the top to the bottom of the series of cores. On this point the evidence appears to be conclusive, and we are justified in stating that no basis of old Tertiary limestone was reached in the deep boring at Funafuti.

In comparing the results obtained by the study of upraised coral reefs, and in a vertical bore-hole, it should be borne in mind that the former can never be expected to supply us with such perfectly unequivocal evidence as the latter. Upraised coral reefs nearly always show indications of having been subjected to various movements, sometimes upwards, at other times downwards, with perhaps intervals of rest between. At any period of their long and complicated history, masses of fringing reef may accumulate around them, and seeing how rapidly

* 'Geographical Journal,' vol. 13 (1899), p. 17. "A Monograph of Christmas Island (Indian Ocean)," published by the Trustees of the British Museum, 1900.

† 'Bull. Mus. Comp. Zool.,' vol. 33 (1899), pp. 1–167; *ibid.*, vol. 38 (1900), pp. 1–50.

great chemical and mineralogical changes may go on in coral-reef limestones, there must always be some element of uncertainty in fixing upon the sequence of rocks in an upraised coral reef such as does not exist in the case of a vertical bore-hole.

It is only fair to point out that in his recent valuable researches on the upraised reefs of the Pacific, Professor AGASSIZ has taken every possible precaution to avoid these obvious sources of error. Wherever possible, the specimens collected were obtained in deep ravines, and by means of blasting; but even when all this was done, the series of specimens collected must have been very far from constituting a vertical sequence, like those from a bore-hole.

B.—*The Materials from the Lagoon of Funafuti.*

The specimens collected from the lagoon of Funafuti are of scarcely less interest and importance than those obtained from the several borings in the islets of the atoll. The lagoon of Funafuti has an extreme length from north to south of 14 miles, and a breadth from east to west of 9 miles. Its depth varies from 12 to 30 fathoms, with a probable average of 20 fathoms. There are wide and deep openings between the islets encircling the atoll, especially on the south-east and north-west sides. Consequently this body of salt water (which is as deep as the Straits of Dover) is in free communication with the open ocean, and, though affording a safe anchorage ground, is by no means a mass of still or dead water. The communication with the open ocean is so free that, contrary to what is the case in the neighbouring atoll of Nukulailai, the waters of the lagoon flow freely in and out at the change of the tides, and there is never any difference of level between the lagoon and the outer ocean. The inflowing and outflowing waters probably find their way, not only through the wide and deep channels between the islets, but to some extent through the body of the reef, which in its upper portions would appear to be almost as open and pervious as a sponge.

Besides a number of sporadic dredgings within its area, we have the results, a very systematic examination of the floor of the Funafuti Lagoon. Mr. G. H. HALLIGAN and Mr. A. E. FINCKH made a series of dredgings with the sand-pump at distances of $\frac{1}{2}$ mile from a point opposite to the Mission Church at Fongafale (Funafuti Island) in a direction slightly north of west to Fuafutu Island. (See Plate 1.) The former gentleman, with the aid of Commander STURDEE, R.N., and of the officers and men of H.M.S. "Porpoise," was able to put down two borings in the lagoon, about $1\frac{1}{2}$ miles west of the Mission Church, and slightly north of the line of dredgings. The depth of the lagoon where the boring was made was 101 feet, and the deepest of the borings was carried to 245 feet from low-water mark spring tides, or 144 feet below the floor of the lagoon.

The dredgings in the lagoon showed that except where bosses of coral rock rise

and form shoals, often with only a few feet of water upon them at high tide, the whole of the bottom of the Funafuti Lagoon is covered with a dense growth of the green calcareous alga *Halimeda opuntia* LAM., a well-known member of the order Siphoneæ, group Chlorophyceæ. This growth of *Halimeda* appears to be most vigorous in the shallower parts of the lagoon, but everywhere it forms a green living carpet down to depths of 120 feet, and is occasionally found alive at greater depths. The *Halimeda* fronds are often more or less covered with attached organisms, such as the foraminifera *Sagenina*, *Polytrema*, &c., with *Spirorbis*, *Serpulæ*, Polyzoa, &c., and other organisms. Intermingled with the living *Halimeda* and its broken and dead remains are found numerous foraminifera, with Ostracoda and alcyonarian and tunicate spicules, as well as remains of Pteropoda, Gastropoda, Pelecypoda, Crustacea and other forms of animal life, with several forms of *Lithothamnion*. In the central and deeper parts of the lagoon the number of foraminifera is comparatively small, seldom exceeding 10 per cent. of the whole mass, and consisting only of species adherent to the fronds of *Halimeda*, with the free forms *Amphistegina* and *Heterostegina*. But in the shallower water on the edges of the lagoon, the foraminifera and other organisms increase in number till they constitute the bulk of the materials of the sandy bottom. As shown by Mr. CHAPMAN, the forms of foraminifera are more numerous and varied at the Fuafatu end of the line of soundings, where the lagoon is open to the ocean, than at the more enclosed end at Fongafale.*

The genera of foraminifera which abound in the shallow water are the same as those found on the lagoon beaches, and include the conspicuous spurred forms *Calcarina* and *Tinoporus*, with many species of *Miliolina*, while the different varieties of *Orbitolites*, *Globigerina* and other pelagic forms occur much more rarely, and usually as dwarfed specimens; these were probably washed in from the ocean outside. On the lagoon shore at Fongafale, twenty-one species of foraminifera are recorded by Mr. CHAPMAN as occurring, while at the Fuafatu shore of the lagoon the number is twenty-eight, the increase being accounted for by the greater increase of marine conditions, due to wide openings in the atoll-rim and the richer supply of food. The effect of advantageous conditions is shown by increase in the size of individuals as well as by the number and diversity of species.

The proportions of the several kinds of organisms in the eighteen samples dredged in the lagoon, at distances of half a mile from Fongafale to Fuafatu, were determined by taking weighed portions and picking out the various organisms. The results obtained were as follows :—

* F. CHAPMAN, "Foraminifera from the Lagoon of Funafuti," 'Linn. Soc. Journ.' (Zoology), vol. 28 (1901–03), pp. 161–210.

Number of sample.	Depth in fathoms.	Percentage of *Halimeda*.	Percentage of Foraminifera.	Percentage of other organisms.
1	10	50	47	3
2	15½	75	23	2
3	20	99	½	½
4	23	76	20	4
5	24	85	14	1
6	21	90	9	1
7	24	85	14	1
8	26	97	2	1
9	25	98	1	1
10	26	85	12½	2½
11	25	85	12½	2½
12	23	98	1	1
13	26	90	9	1
14	16	90	9	1
15	19	90	9	1
16	20	90	9	1
17	12	9	90	1
18	½	1	98	1

The samples obtained by Mr. HALLIGAN in his important boring in the floor of the lagoon, were as far as possible treated in the same way, but those from the lower portion of the bore had the organisms so firmly compacted together that it was impossible to separate them by picking.

Down to the depth of 163 feet from the sea-level (62 feet below the floor of the lagoon), the materials consisted of "*Halimeda* sand" with an admixture of foraminifera and other organisms. The foraminifera consisted of *Amphistegina* and *Heterostegina*, with attached genera like *Polytrema*, *Carpenteria*, *Sagenina*, &c., and an admixture of littoral forms like *Calcarina*, *Orbitolites*, &c.

The proportions of *Halimeda* fronds to the foraminifera and other organisms in the five samples obtained, from the upper part of the boring, as determined by picking weighed portions, is as follows :—

Number of sample.	Depth in feet.		Percentage of *Halimeda*.	Percentage of Foraminifera.	Percentage of other organisms.
	From surface.	From floor of lagoon.			
L.1	101	0	82	15	3
L.2	122½	21½	84¼	14½	1¼
L.3	136½	35½	96¾	3	¼
L.4	151	50	87½	11½	1
L.5	163	62	84½	12	3½

Below the depth of 62 feet (163 feet below sea-level) the boring-tools entered a mass of loosely compacted coral rock similar to that met with in the upper part of all

the borings in the island of Funafuti. In these loose materials there occurred more firmly compacted masses of coral rock, which were penetrated with great difficulty, under the unfavourable conditions in which the work of boring was carried on. At a depth of 177 feet (76 feet below the floor of the lagoon) a solid mass 5 feet thick was bored through, at 217 feet another solid mass 18 inches thick was penetrated, and from the material broken up and disintegrated by the boring tools, fragments, angular and subangular, up to the size of a walnut were brought up. The boring was stopped at a depth of 245 feet by solid coral rock which could not be penetrated with the appliances available.

In the second boring, which was made at a distance of only 90 feet north of the first one, a similar section was obtained. Under the *Halimeda* sand, which was from 60 to 70 feet thick, coral rock was found, which broke up under the boring tools, but there was a more solid mass 3 feet thick (with some softer partings) at a depth of 92 feet from the bottom of the water in the lagoon. This second boring was carried to a depth of 214 feet in the easily disintegrated coral rock before hard impenetrable masses were met with.

The numerous fragments of corals obtained in these lagoon borings beneath the *Halimeda* sand, have been very carefully studied by Dr. HINDE and Mr. BERNARD, while the foraminifera have been determined by Mr. CHAPMAN. Of course, made as the borings were (see Mr. HALLIGAN'S report p. 161), no solid cores like those obtained by the aid of the diamond drill could be secured, but the numerous fair-sized angular fragments evidently broken off by the edge of the tube and by the boring chisels, supplied sufficient evidence as to the nature of the solid rock passed through.

Specimens of all the reef-forming and other genera of corals which occur in the main boring were obtained from the boring in the lagoon. They include such forms as *Heliopora*, *Madreporaria* (*M. contecta* being present), *Montipora*, *Porites*, *Pocillopora*, *Goniopora*, *Astræopora*, *Lobophytum*, *Cœloria*, *Fungia*, *Cyphastræa* and other Astræan corals, *Seriatopora*, &c. The most numerous foraminifera are those belonging to the genera *Amphistegina* and *Heterostegina*, but *Polytrema planum* and other encrusting forms are common, while all the genera which occur abundantly in the main boring are found to be represented in the rocks passed through in the lower part of the lagoon boring. Here, too, were found the usual mollusca, and other organisms of the reef, with alcyonarian and tunicate spicules; *Lithothamnion* and *Halimeda* are also present in considerable abundance.

This evidence indicates that at a depth of more than 40 fathoms in the lagoon of Funafuti, we have a rock built up of the common reef-forming corals, with the other organisms usually associated with them. This mass of coral rock would appear to lie generally at depths of from 36 to 40 fathoms from the surface of the water in the lagoon, but in places to form bosses that constitute shoals only covered at high tide. In these shallower portions of the lagoon the corals are found to be still alive and growing.

Over the greater part of the lagoon floor, however, there would appear to be a turf-like growth of the green calcareous alga *Halimeda*. In the shallower portions of the lagoon this *Halimeda* growth appears to be most vigorous and constitutes a green carpet on the lagoon floor; but in deeper portions of the lagoon, the *Halimeda* appears to be dead and decaying. Towards the edges of the lagoon and around the various shoals in it, the mass of living and dead *Halimeda* fronds gives place to the usual shore-sands largely composed of foraminifera.

We have fortunately the means supplied to us by the observations of Mr. FINCKH (see page 146) of estimating the rate of growth of *Halimeda*, and of comparing it with that of various genera of corals. A tuft of *Halimeda* forming a compact boss $2\frac{1}{4}$ inches (55 millims.) high, and $3\frac{1}{4}$ inches (80 millims.) in diameter, grew up in six weeks! No coral of which the rate of growth has been studied has anything like this power of rapid development. *Lithothamnion* too, seems, in spite of its ubiquitous character, to be a much more slowly growing organism than *Halimeda*. It would appear that while in some parts the growth of corals was choked by the covering of *Halimeda*, in other places the corals conquered in the struggle for life, and continued to grow upwards. A great part of the lagoon of Funafuti is thus proved to be covered by a mass of calcareous algæ, and this mass of vegetable matting has a remarkable resemblance to a peat-bog. The upper surface is green and living, but, below, the mass is dead and decaying. The depth of this mass of living and dead vegetable matter appears to be between 60 and 70 feet, and it lies between and around upgrowing bosses of coral rock that form shoals.

The rate of growth of the tuft of *Halimeda* studied by Mr. FINCKH may not improbably have been exceptionally rapid, for the conditions were perhaps unusually favourable in the shallow waters where the experiment took place. But it is possibly not an excessive estimate to take 1 inch per annum as the rate of accumulation of the broken fronds of *Halimeda* on the lagoon floor. At this rate of accumulation the mass of vegetable matter on the floor would represent a period of about 800 years. If we take 15 fathoms as the depth at which the vigorous growth of reef-forming corals goes on (and this is in conformity with the results obtained by Professor A. AGASSIZ and Mr. STANLEY GARDINER), a subsidence of 25 fathoms (150 feet) must have taken place in this 800 years, being at the rate of less than 20 feet per century.

We have compared this mass of vegetable matter, alive on its surface and dead below, to a peat-bog, and there is another respect in which the analogy holds good. In a peat-bog the lower portions are undergoing slow chemical changes, various gases being given off, the proportion of carbon to the other constituent elements showing a progressive and constant increase as we go downwards. Dr. HINDE has pointed out that in going downwards through the mass of *Halimeda* fronds on the lagoon floor, we find first the organic matter disappearing, and the fronds becoming white and friable, and afterwards these fronds becoming more solid and dense by a secondary deposit of calcium carbonate. The exact nature of the changes taking place

will be discussed in the section (XII) on the chemistry of the rocks of the Funafuti Atoll.

C. *Other Materials Collected from the Islets of the Funafuti Atoll and from the Ocean around it.*

Professor SOLLAS collected, during the first expedition to Funafuti in 1896, a very interesting series of sands, and of the consolidated coral rock of the various islets, and these have been sent to me for examination. Mr. STANLEY GARDINER and Mr. HEDLEY, who accompanied the same expedition as volunteers, brought to Cambridge and Sydney respectively large and valuable collections representing the fauna, flora, and anthropology of Funafuti and of the other islands of the Ellice Group.

Under the advice of the Coral Reef Committee, the Council of the Royal Society decided that the result of the study of all the material brought home from Funafuti might be published in the various scientific journals, as soon as could be conveniently arranged, and there is already, as will be seen from the list given on pages 182–185, a considerable body of scientific literature on the natural history of Funafuti, a large number of new species and varieties having been described from the collections brought home, while discussions on the geology, anthropology, and general natural history of the island have been published by different authors.

In the Second Expedition in 1897, Professor DAVID and Mr. SWEET, besides collecting specimens to illustrate their account of the geology of the various islets, made special attempts to study the nature of the organisms growing on the reef face down to the depth of 200 fathoms. This task proved to be a very difficult, and not seldom a dangerous one, but by means of the apparatus that has been described, fragments of organisms, often living, were broken from the face of the reef, and brought home either in spirits or as dried specimens. All these collections have been submitted to specialists at the British Museum and elsewhere, and all new species that have been detected have been described in the scientific journals.

The foraminifera from these collections have been very fully described and their distribution discussed by Mr. CHAPMAN.* The question of the distribution of other forms obtained from the reef face in a living state has not yet received the attention which it deserves.

In the deep soundings carried on by Captain A. MOSTYN FIELD, R.N., in H.M.S. "Penguin," in the year 1896, when so complete a survey of the Funafuti Atoll and of the surrounding sea was made, a number of small specimens of the ocean floor, often at great depths, were obtained. These I have received from Admiral Sir W. J. L. WHARTON and Professor SOLLAS, and their description will be undertaken by Mr. F. CHAPMAN, who is now at Melbourne.

* 'Linn. Soc. Journ.' (Zoology), vol. 28 (1900–03), pp. 1–27 and pp. 379–433.

The description of the collections made on the face of the reef down to 200 fathoms, will be undertaken by Professor DAVID and his assistants at Sydney.

List of Memoirs in which Materials obtained during the three Expeditions to Funafuti have been described.

PLANTS.

M. FOSLIE.—"Notes on Two *Lithothamnia* from Funafuti." 'Kgl. Norske Videnskabers Selskabs Skriften,' 1899.

M. FOSLIE.—"Calcareous Algæ from Funafuti." *Ibid.*, 1900.

M. FOSLIE.—"New or Critical Calcareous Algæ." *Ibid.*, 1900.

M. FOSLIE.—"Remarks on Melobesiæ in Herbarium Cronan." *Ibid.*, 1900.

Miss E. S. BARTON (Mrs. GEPP).—"On the Forms, with a New Species, of *Halimeda* from Funafuti." 'Linn. Soc. Journ.' (Bot.), vol. 34 (1900), p. 479. One plate.

Miss E. S. BARTON (Mrs. GEPP).—"The Genus *Halimeda*." 'Monographie LX, Uitkomsten op Zoologisch, Botanisch, Oceanographisch en Geologisch Gebied Siboga Expeditie.' Four plates.

FORAMINIFERA.

F. CHAPMAN.—"On some New and Interesting Foraminifera from Funafuti Atoll, Ellice Islands." 'Linn. Soc. Journ.' (Zool.), vol. 28 (1900–03), pp. 1–27. Four plates.

F. CHAPMAN.—"Foraminifera from the Lagoon at Funafuti." *Ibid.*, pp. 161–210. Two plates.

F. CHAPMAN.—'On the Foraminifera collected round the Funafuti Atoll from Shallow and Moderately deep Water.' *Ibid.*, pp. 379–417. Two plates. (Other memoirs on Funafuti material are in preparation by this Author.)

F. CHAPMAN.—"On the Identity of *Polytrema planum* of CARTER with *P. miniaceum* var. *involva*." 'Ann. and Mag. Nat. Hist.,' Ser. 7, vol. 7 (1901), pp. 82–3.

SPONGES.

T. WHITELEGGE.—'The Sponges of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 323–332.

R. KIRKPATRICK.—"Description of Sponges from Funafuti." 'Ann. and Mag. Nat. Hist.,' Ser. 7, vol. 6 (1900), pp. 345–362. Three plates.

J. LISTER.—"*Astrosclera Willeyana*, the type of a new Family of Sponges." 'A. Willey's Zoological Results,' Part IV (1900), pp. 459–482. Four plates.

HYDROZOA.

T. WHITELEGGE.—'The Hydrozoa of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 373–383.

SYDNEY HICKSON.—"On the Species of the Genus *Millepora*, a Preliminary Communication." 'Proc. Zool. Soc.,' 1898, pp. 246–257.

SYDNEY HICKSON.—'Notes on the Collections of Specimens of the genus *Millepora* obtained by Mr. STANLEY GARDINER at Funafuti and Rotuma.' *Ibid.*, pp. 828–833.

SCYPHOZOA.

T. WHITELEGGE.—'On the Scyphozoa of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 383–384.

ACTINOZOA.

T. WHITELEGGE.—'The Alcyonaria of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 213–225, 307–320.

Miss ISA L. HILES.—"Report on the Gorgonacean Corals collected by Mr. J. STANLEY GARDINER at Funafuti." 'Proc. Zool. Soc.,' 1899, pp. 46–54. Four plates.

T. WHITELEGGE.—'The Madreporaria of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 349–368.

J. STANLEY GARDINER.—"On some Collections of Corals of the Family Pocilloporida from the South-West Pacific Ocean." 'Proc. Zool. Soc.,' 1897, pp. 941–953. Two plates.

J. STANLEY GARDINER.—"On the Perforate Corals collected by the Author in the South Pacific." 'Proc. Zool. Soc.' 1898, pp. 257–276. Two plates.

J. STANLEY GARDINER.—"On the Fungid Corals collected by the Author in the South Pacific." 'Proc. Zool. Soc.,' 1898, pp. 525–539. Three plates.

J. STANLEY GARDINER.—"On the Turbinolid and Oculinoid Corals collected by the Author in the South Pacific." 'Proc. Zool. Soc.,' 1898, pp. 994–1000. One plate.

J. STANLEY GARDINER.—"On the Astræid Corals collected by the Author in the South Pacific." 'Proc. Zool. Soc.,' 1899, pp. 734–764. Four plates.

H. M. BERNARD.—'In the Appendix to vol. 3 of the British Museum Catalogue of Corals (Montipora).'

GILBERT C. BOURNE.—"Some New and Rare Corals from Funafuti." 'Linn. Soc. Journ.' (Zoology), vol. 29 (1903), pp. 26–37. Two plates.

Echinodermata.

T. Whitelegge.—'The Echinodermata of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 155–162.

F. P. Bedford.—"Report on the Holothurians collected by Mr. J. Stanley Gardiner at Funafuti and Rotuma." 'Proc. Zool. Soc.,' 1898, pp. 834–848. Two plates.

F. Jeffrey Bell.—"On the Actinogonidiate Echinoderms collected by Mr. J. Stanley Gardiner at Funafuti and Rotuma." 'Proc. Zool. Soc.,' 1898, pp. 849–850.

Vermes.

T. Whitelegge.—'The Vermes of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 392–394.

A. E. Shipley.—"Report on the Gephyrean Worms collected by Mr. J. Stanley Gardiner at Rotuma and Funafuti." 'Proc. Zool. Soc.,' 1898, pp. 468–473. One plate.

F. F. Laidlaw.—"Notes on some Marine Turbellaria from Torres Straits and the Pacific, with a description of new species." 'Mem. Proc. Manchester Lit. Phil. Soc.,' vol. 47 (1903), No. V, pp. 1–12.

Mollusca.

C. Hedley.—'The Mollusca of Funafuti, Part I, Gasteropoda.' Memoir III, Australian Museum, Sydney, pp. 395–488.

C. Hedley.—'The Mollusca of Funafuti, Part II, Pelecypoda and Brachiopoda.' Memoir III, Australian Museum, Sydney, pp. 491–510.

C. Hedley.—'The Mollusca of Funafuti (Supplement).' Memoir III, Australian Museum, Sydney, pp. 549–565.

Arthropoda.

W. J. Rainbow.—'The Insect Fauna of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 89–102.

W. J. Rainbow.—'The Arachnidan Fauna of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 105–124.

T. Whitelegge.—'The Crustacea of Funafuti,' Memoir III, Australian Museum, Sydney, pp. 127–151.

L. A. Borradaile.—"On some Crustaceans from the South Pacific, Part I, Stomapoda." 'Proc. Zool. Soc.,' 1898, pp. 32–38. Two plates.

L. A. BORRADAILE.—"On some Crustaceans from the South Pacific, Part II, Macrura Anomala." 'Proc. Zool. Soc.,' 1898, pp. 457–468. One plate.

L. A. BORRADAILE.—"On some Crustaceans from the South Pacific, Part III, Macrura." 'Proc. Zool. Soc.,' 1898, pp. 1000–1015. Three plates.

L. A. BORRADAILE.—"A Revision of the Pontoniidæ." 'Ann. and Mag. Nat. Hist.,' Ser. 7, vol. 2 (1898), pp. 376–391.

L. A. BORRADAILE.—"On some Crustaceans from the South Pacific, Part IV, The Crabs." 'Proc. Zool. Soc.,' 1900, pp. 568–596. Three plates.

L. A. BORRADAILE.—"On some Crustaceans from the South Pacific, Part V, *Anthrostraceans* and *Barnacles*." 'Proc. Zool. Soc.,' 1900, pp. 795–799. One plate.

R. J. POCOCK.—"List of Arachnida and 'Myriapoda' obtained in Funafuti, by Professor W. J. SOLLAS and Mr. STANLEY GARDINER, and in Rotuma by Mr. STANLEY GARDINER." 'Ann. and Mag. Nat. Hist.,' Ser. 7, vol. 1 (1898), pp. 321–329.

F. CHAPMAN.—"On some Ostracoda from Funafuti." 'Linn. Soc. Journ. (Zoology),' vol. 28 (1900–3), pp. 417–433. One plate.

ENTEROPNEUSTA.

J. P. HILL.—'The Enteropneusta of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 205–210, 335–346.

VERTEBRATA.

E. R. WAITE.—'The Mammals, Reptiles, and Fishes of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 165–201.

E. R. WAITE.—'The Fishes of Funafuti (Supplement).' Memoir III, Australian Museum, Sydney, pp. 537–546.

A. J. NORTH.—'Aves from Funafuti.' Memoir III, Australian Museum, Sydney, pp. 79–86.

H. GADOW.—'A List of the Birds of the Island of Rotumah.' Ibis, January 7, 1898, pp. 42–46. (Includes list of Funafuti birds.)

ETHNOLOGY.

C. HEDLEY.—'The Ethnology of Funafuti.' Memoir III, Australian Museum, Sydney, pp. 227–304.

See also general account, *Ibid.*, pp. 41–71.

W. J. SOLLAS.—"The Legendary History of Funafuti," 'Nature,' February 11, 1897 (vol. 55, p. 353).

SECTION XI.

REPORT ON THE MATERIALS FROM THE BORINGS AT THE FUNAFUTI ATOLL.

By GEORGE JENNINGS HINDE, *Ph.D.*, *F.R.S.*

CONTENTS.

(1).—INTRODUCTION.

ON the invitation of the Coral Reef Committee of the Royal Society, I undertook, in February 1900, an examination of the materials obtained from the various borings sunk on the reef and beneath the floor of the lagoon of the Funafuti Atoll, in 1896–1898, with the object of determining the nature and distribution of the organisms which have contributed to the building up of the atoll. Of the three borings carried out on the reef the most important was that known as the Main Boring, which reached a depth of 1114½ feet from the surface; the two earlier attempts of Professor SOLLAS, known as the First (C), and Second (D) Borings, did not extend deeper than 105 feet and 72 feet respectively. The borings in the lagoon reached a depth of 144 feet below the floor of the lagoon. The materials from these borings consist of solid cylindrical cores and irregular nodular lumps of limestone or dolomitic rock, together with loose, fragmentary, granular and powdery material, partly of small organisms, partly of broken-up limestone. The solid cores and the samples of loose materials from each boring were kept distinct, and they had all been brought to England and deposited provisionally in the Geological Laboratory of the Royal College of Science, South Kensington, under the charge and supervision of Professor J. W. JUDD, F.R.S.

To facilitate examination, the longer cylindrical cores of the Main Boring were cut transversely into pieces of 5 or 6 inches (125–150 millims.) each in length, and these and all the other cores from the different borings, both cylindrical and nodular, were slit longitudinally by a lapidary's wheel armed with diamond dust. As the result of this process the median face of each half of the core (where the rock was sufficiently hard), was left nearly as smooth and even as if it had been polished, so that its structure could be readily distinguished with a lens. More than 400 microscopic sections were also prepared from longitudinal and transverse slices of the solid cores wherever it seemed desirable to study in detail the structure of the rock and of the organisms in it, and thin sections of the incoherent fragmental materials were likewise skilfully prepared by Mr. F. CHAPMAN. The slow and tedious work of slitting over 400 feet of the rock-cores, and the preparation of the microscopic slides, were efficiently carried out at the Geological Laboratory under the direction of Professor JUDD.

A partial study of the cores from the upper part of the Main Boring had already been made by Professor T. W. EDGEWORTH DAVID, F.R.S., and with his approval I have availed myself of his notes and followed generally the lines of investigation which he had begun.

For the determination of the Foraminifera shown in the microscopic sections and in the loose materials from the borings, I have relied upon the authority of Mr. F. CHAPMAN.* His study of the recent forms of the group dredged from the outer slopes of the reef and from the lagoon at Funafuti, render his determinations of the forms embedded in the cores especially valuable. I am myself responsible for noting the common and familiar kinds present in nearly all the cores of the various borings.

I also wish to acknowledge my indebtedness to Mr. J. STANLEY GARDINER for the loan of recent corals which he had collected at Funafuti, and for examining some of the fossil forms from the borings.

The measurements of the borings and cores taken on the spot in English feet and inches, have been retained in the report without alteration, but for measuring the separate pieces of core it has been more convenient to adopt the metric system.

(2).—GENERAL FEATURES OF THE MAIN BORING.

The Main Boring on the Funafuti Atoll was commenced in 1897, under the direction of Professor T. W. EDGEWORTH DAVID, and carried down in that year to the depth of 698 feet. In the following year the boring was resumed under the charge of Mr. A. E. FINCKH, and continued to the depth of 1114½ feet from the surface. The diameter of the cores brought up in the core barrel was as follows: From the surface to 68 feet, about 4 inches (103 millims.); from 68–210 feet about 3¼ inches

* 'Linn. Soc. Journ.,' Zoology, vol. 28 (1900–3), pp. 1–27, 161–210, Plates 1–4, 19, 20.

(81 millims.); and from 210–1114½ feet about 2¼ inches (58 millims.). The rock cores were very unequal in length, ranging from 1 inch (25 millims.) to 3 feet (900 millims.), and in many instances only imperfect cylinders and nodular fragments were obtained. Each separate cylinder and nodule of core was numbered consecutively; from the surface to the depth of 698 feet, reached by the end of the first year's work, the numbers of the cores ran from 1–366; on resuming the boring the second year a fresh series of numbering was introduced, and the cores between 698 feet and the bottom of the boring at 1114½ feet were marked 1A–709A.

The solid rock cores, however, by no means represent all the material brought up from the boring, for from the surface to a depth of 748 feet, *i.e.*, about two-thirds of the distance passed through, a large proportion of the rock was of so friable and incoherent a character that in the process of boring it broke up into fine granular particles and powdery material, to which those engaged in the boring applied the general term of "sand."* This granular material was brought up from the boring by means of the sand-pump, and from samples of it taken at intervals of a few feet, it appears to have been derived for the most part from a porous rubbly limestone, which consisted of foraminifera, small pieces of casts of corals, alcyonarian spicules, echinoid spines and plates, fragments of calcareous algæ and the *débris* of various other organisms with fine sediment. No true oolitic grains were noticed either in the solid cores or loose materials. These fragmentary materials, in some samples from no great depth from the surface, appear to have been but little more than compressed together, but more generally they have been lightly cemented by crystalline calcium carbonate. Their ready disintegration seems to be in great part due to the slight development of the crystalline cementing matrix; it is probably also connected with the solution or decomposition of the corals which takes place below the depth of 200 feet, to which we shall again refer. That the present friable, incoherent condition of the rock which furnishes this fine granular material, depends on other circumstances than the detached fragmentary character of its constituent organisms is shown by the fact that where the small interstices between the organic fragments are fairly well occupied by crystalline calcite, or, better still, by crystalline dolomite, a very fine, hard, resistant rock is produced. Many of the hardest rock-cores are seen on microscopic examination to consist of foraminifera and other fragmentary organisms thus consolidated.

The amount of the consolidated rock-cores, as distinct from the fragmentary incoherent material, is shown in the following list (p. 189). Their aggregate length is 384⅓ feet, or an average in round numbers of 1 foot of core in each 3 feet of the boring.

* This material differs so greatly from "sand," as generally understood, that so to term it would give an erroneous idea of its real character, and I have therefore avoided the use of the word in referring to this fine material.

LIST showing the Length and Numbers of the Cores from various Depths of the Main Boring, Funafuti.

Depth from surface in feet.	Distance bored.	Total length of core obtained.		Numbers of cores.	Depth from surface in feet.	Distance bored.	Total length of core obtained.		Numbers of cores.
	ft.	ft.	in.			ft.	ft.	in.	
0–10	10	2	10	1–11	Brought				
10–20	10	2	5	12–18	forward	643	55	6	
20–30	10	3	4	19–33	643–652	9	3	5	321–335
30–40	10	4	4	34–55	652–660	8	1	9	336–343
40–50	10	1	1	56–59	660–670	10	0	8	344–347
50–60	10	1	2	60–67	670–691	21	1	11	348–356
60–70	10	2	2	68–84	691–698	7	2	2	357–366
70–80	10	1	1	85–93	698–706	8	0	8	1A–2A
80–90	10	1	4	94–99	706–716	10	1	0	3A–8A
90–100	10	1	1	100–108	716–736	20	2	4	9A–16A
100–110	10	0	7	109–115	736–748	12	3	5	17A–31A
110–120	10	0	8	116–120	748–763	15	7	1	32A–54A
120–130	10	2	4	121–129	763–771	8	5	3	55A–73A
130–140	10	1	0	130–134	771–781	10	6	11	74A–96A
140–150	10	0	5	135–137	781–790	9	7	10	97A–122A
150–160	10	0	5	138–141	790–798	8	7	5	123A–144A
160–170	10	0	0	142–143	798–804	6	4	1	145A–156A
170–180	10	1	4	144–150	804–810	6	5	1	157A–174A
180–190	10	1	2	151–158	810–815	5	3	6	175A–186A
190–200	10	4	8	159–175	815–822	7	4	5	187A–197A
200–210	10	0	10	176–178	822–833	11	7	11	198A–215A
210–220	10	0	9	179–185	833–844	11	10	6	216A–234A
220–230	10	0	4	186	844–853	9	7	2	235A–248A
230–240	10	0	0	187–188	853–866	13	10	11	249A–276A
240–280	40	0	1	189–198	866–874	8	5	4	277A–296A
280–330	50	0	0	—	874–881	7	6	2	297A–310A
330–373	43	0	0	—	881–890	9	7	11	311A–325A
373–378	5	1	9	199–206	890–899	9	8	5	326A–340A
378–410	32	0	0	—	899–910	11	11	0	341A–353A
410–420	10	0	10	207–213	910–922	12	11	4	354A–376A
420–450	30	1	6	214–222	922–936	14	13	9	377A–404A
450–457	7	1	5	223–229	936–945	9	8	4	405A–421A
457–468	11	0	7	230–233	945–957	12	10	11	422A–442A
468–480	12	0	6	234–236	957–963	6	5	11	443A–449A
480–487	7	0	0	—	963–973	10	9	7	450A–470A
487–497	10	1	1	237–241	973–983	10	8	5	471A–490A
497–505	8	0	10	242–252	983–991	8	7	1	491A–507A
505–517	12	0	7	253–258	991–1006	15	12	8	508A–527A
517–526	9	1	4	259–267	1006–1015	9	8	6	528A–542A
526–546	20	4	0	268–289	1015–1025	10	8	3	543A–564A
546–555	9	0	10	290–296	1025–1034	9	8	10	565A–583A$_1$
555–567	12	0	0	—	1034–1044½	10½	10	5	583A$_2$–594A
567–578	11	0	2	296*a*–296*b*	1044½–1053	8½	7	7	595A–607A
578–598	20	0	10	297–304	1053–1066	13	9	9	608A–627A
598–612	14	0	10	305–306	1066–1075	9	7	9	628A–643A
612–624	12	0	0	—	1075–1087	12	10	6	644A–661A
624–637	13	0	11	307–312	1087–1100	13	12	2	662A–682A
637–643	6	2	1	313–320	1100–1114½	14½	12	10	683A–709A
Carried forward	643	55	6		Total ...	1114½	384	4	

But there is a very striking difference in the proportion of the solid cores in various parts of the boring, for while in the upper part, from the surface to the depth of 748 feet, the total length of solid rock-core is only 72¾ feet, or about one-tenth of the distance bored, in the lower part, from 748 feet to the bottom of the boring at 1114½ feet, the length of the solid cores reaches 311½ feet, or 85 per cent. of the distance. It may be said that practically the lower third, or 366 feet, of the boring is a continuous core of solid rock; the upper two-thirds, on the other hand, is mainly of incoherent or lightly cemented rock, with only one-tenth sufficiently consolidated to be brought to the surface as firm core. It is to be noted, moreover, that the rock in the higher part of the boring is to a large extent a limestone, and that in the lower part a dolomite or dolomitic limestone.

The material from the boring, whether in the form of solid rock-cores or as incoherent granular particles, appears to be entirely of organic character, and derived from the calcareous skeletons of marine invertebrate animals and calcareous algæ. Though there is abundant evidence that siliceous sponges were very numerous, for the corals in the cores are riddled in all directions by their characteristic tunnellings, their spicules have altogether disappeared, and the silica which might have resulted from their solution has not been traced, for there is no indication that any of the corals or other organisms have been replaced by this mineral. Not a trace of pumice or of any other volcanic product has been noticed from any part of the boring.

The following condensed account of the materials from the boring is intended to give an idea of the general characters of the rock and the organisms in it. The detailed description of the cores appears in the sequel:—

Depth from Surface in feet 0–150. *Distance Bored in feet* 150.
Numbers of Cores 1–137.

The total length of the solid cores in this part of the boring is nearly 26 feet, or about one-sixth of the distance passed through. The rock is a whitish or cream-coloured limestone with patches of a dirty-green tint wherever *Heliopora cærulea* occurs. It is mainly composed of corals (including Hydrocorallinæ and Alcyonaria with the Madreporaria), which under the microscope are seen to retain their minute structures with but little alteration, though they are often rendered very obscure by a secondary deposition in the interior of the corallites of sclerenchyma and crystalline "conchite" or aragonite. The predominant forms belong to *Millepora*, *Heliopora*, *Pocillopora* and *Madrepora*; other genera, less numerously represented, are *Lobophytum*, *Stylophora*, *Astræa*, *Orbicella*, *Astræopora*, *Porites* and *Montipora*. A new species of *Madrepora*, which* I have named *M. contecta*, is very abundant, the cores between 50 and 80 feet largely consisting of it. *Heliopora cærulea* is also common, more particularly in the first 40 feet of the boring.

* See p. 326.

The solid cores in this part of the boring, composed as they are mainly of corals, may be considered as indicating the proportion of the general mass of the rock due to these organisms. Making allowance for those which may have decayed or otherwise been reduced to fragments and so have passed into the incoherent materials, it would appear that only about one-fifth of this part of the boring is formed ot corals.

The greater part of the material from the boring consists of foraminifera and other organisms, chiefly fragmentary, which, together with fine detrital sediment, forms a chalky-looking powder, which, in places, is cemented into hard rock. The greater number of the foraminifera belong to the following genera :—*Orbitolites*, *Carpenteria*, *Tinoporus*, *Gypsina*, *Polytrema*, *Amphistegina* and *Heterostegina*. The rarer forms, determined by Mr. CHAPMAN, include *Nubecularia*, *Miliolina*, *Placopsilina*, *Haddonia*, *Textularia*, *Cristellaria*, *Sagrina*, *Globigerina*, *Spirillina*, *Discorbina*, *Planorbulina*, *Truncatulina*, *Pulvinulina* and *Rotalia*.

The other constituents of the incoherent material are calcisponge spicules, alcyonarian spicules, spines and detached test-plates of echinids, annelid tubes, entomostraca (*Bairdia*), limbs of small crabs, polyzoa, brachiopods (*Thecidea maxilla*), lamellibranchs, gastropods, stellate spicules of ascidians (*Leptoclinum*) and small coprolitic pellets. The calcareous algæ include detached joints of corallines, *Halimeda* and *Lithothamnion*, both branching and encrusting.

Depth from Surface in feet 150–230. *Distance Bored in feet* 80.
Numbers of Cores 138–186.

The length of the solid cores in this portion of the boring is altogether 9½ feet. The rock is a softer and more porous limestone than that above, and the dissolving away of some of the organisms in it frequently renders it cavernous. The characters are scarcely recognisable except in microscopic sections; from these it is seen to consist principally of foraminifera, with occasional corals or casts of corals, embedded in fine sediment and consolidated by crystalline calcite. Below the level of 180 feet the corals have undergone an important change, their walls for the most part have been dissolved and removed, and they are now in the condition of casts or moulds of crystalline material, or of fine calcareous sediment, sometimes so friable that it readily crumbles between the fingers. The corals are often overgrown by layers of *Lithothamnion* and the encrusting foraminifer, *Polytrema planum*, organisms less subject to change in the fossilisation, and their fragile casts are thereby protected to a certain extent, but not infrequently these organic encrustations now only surround a cavity, occupied originally by the coral. This partial destruction and obliteration of the coral structure continues, with some modifications, throughout the remainder of the boring. The forms recognisable in these cores belong to *Millepora*, *Heliopora cærulea*,

Lobophytum, *Stylophora*, *Pocillopora*, *Fungia*, *Astræa*, *Goniastræa*, *Orbicella*, *Madrepora*, and *Porites*.

With some unimportant exceptions the foraminifera and the other organisms in the fine material are the same as those in the boring above. Samples of the broken-up powdered rock appear to be of the same character as that of the solid cores.

Depth from Surface in feet 230–373. *Distance Bored in feet* 143.
Numbers of Cores 187–198.

The only solid core in this 143 feet of the boring is a nodular fragment of white limestone about an inch in diameter. The other material is represented by finely broken-up granular particles of limestone with numerous foraminifera, a small proportion of fragmentary casts of corals, amongst which may be recognised pieces of *Pocillopora*, *Stylophora*, *Cœloria*, *Porites*, and other perforate corals, together with fragments of other organisms of the same kind as those previously noted. The friable character of this rock is probably in part due to the dissolving away of the corals.

Depth from Surface in feet 373–637. *Distance Bored in feet* 264.
Numbers of Cores 199–312.

The solid cores still form only a small proportion of the materials in this boring; their total length is 18 feet, or but little more than one-fifteenth of the distance passed through. They consist of greyish, moderately hard, porous and cavernous limestone, containing foraminifera in great numbers, with some casts of corals and fragments of various organisms, cemented together by crystalline calcite. The cores in which foraminifera preponderate are harder and more compact than those partly formed of coral casts. The coral genera comprise *Lobophytum*, *Pocillopora*, *Seriatopora*, *Stylophora*, *Cœloria*, *Astræa*, *Prionastræa*, *Madrepora*, *Montipora*, and *Porites*. The common foraminifera belong to *Orbitolites*, *Carpenteria*, *Calcarina*, *Polytrema*, and *Amphistegina*. *Cycloclypeus* makes its first appearance in the boring at the depth of 570 feet. Detached alcyonarian spicules, echinid spines, *Serpula* tubes, polyzoa, and casts of gastropods are generally present. *Halimeda*, *Lithothamnion*. Samples of the broken-up, granular, material generally resemble the rock of the solid cores.

Depth from Surface in feet 637–748. *Distance Bored in feet* 111.
Numbers of Cores 313–366, 1A–31A.

Between the depths of 637 feet and 748 feet the rock markedly differs from the hard greyish limestone of the cores immediately above. It becomes milky-white and chalky-looking, soft and very porous, so that it can be crushed between the fingers.

Crystalline dolomite largely replaces calcite as the cementing material. Together with these changes, is an increase in the proportion of the solid core, the length of which altogether is 19 feet or about one-sixth of the distance passed through. The rock cores are mainly composed of foraminifera, and in some portions the detached joints of *Halimeda*, with a few casts of small corals. Nodules formed by the encrusting layers of *Polytrema planum* round corals and other organisms form a prominent feature of the cores. Examples of *Cycloclypeus* are numerous and of very general occurrence in the rock between 643–698 feet. *Alveolina* first appears at the depth of 725 feet and continues down to 740 feet. *Amphistegina* and *Heterostegina* are very abundant.

In addition to the coral genera noted in the core above, the following are present as casts: *Hydnophora*, *Cyphastræa*, *Cycloseris*, *Astræopora* and *Turbinaria*. Encrusting forms of *Lithothamnion* occur, but as a rock former it has here less importance than *Halimeda*.

Depth from Surface in feet 748–1114½. *Distance Bored in feet* 366½.
Numbers of Cores 32A–709A.

The lower third of the boring, from the level of 748 feet to the bottom at 1114½ feet, a distance of 366½ feet, is, with one exceptional interval, of the same general character, and it markedly differs from the middle and upper portions. The rock is a hard, greyish to greyish-brown, dolomitic limestone, porous to compact, according to the measure in which the interspaces have been filled with the crystalline dolomitic matrix; frequently with hollows and cavities where corals and other organisms have been dissolved out, though oftentimes these cavities have been again filled with the crystalline matrix. It is sufficiently consolidated to yield a practically continuous, solid, cylindrical core of the length of 311½ feet. Though the organic remains in this dolomitic rock are often less favourably preserved than those in the limestone rock above, the continuity of the core is better suited for determining the nature and arrangement of the constituent organisms than where the larger part of the rock has been broken up into fine granular material, as is the case in the higher part of the boring.

The rock-forming organisms in this dolomitic rock consist apparently of the same kinds of foraminifera, corals, calcareous algæ, &c., as in the beds above. They show a general disposition in layers or zones in which one or the other of the groups of corals or foraminifera predominate.* The various layers are not distinctly marked off individually, but they gradually merge into each other. Thus for a distance varying from a few inches to several feet the solid cores are principally composed of foraminifera with an admixture of calcareous algæ and fragments of other organisms, but with only a few corals or perhaps none; above and below this layer the rock cores are largely, if not entirely, of casts of corals, but usually some foraminifera, *Lithothamnion*,

* I have not noticed lines of stratification in any part of the cores.

cærulea, with pieces of *Millepora nodosa* and *Madrepora*. The greater part of the core is a hard, grey detrital sediment, with numerous foraminifera, belonging to *Orbitolites*, *Tinoporus*, *Polytrema miniaceum*, *P. planum*, and *Amphistegina*. *Lithothamnion*. Gastropod shells.

(3) [503]. Length 120 millims. Core cylindrical, composed of lumps of *Millepora nodosa*, *Heliopora cærulea*, and pieces of Alcyonarian stems, referred to *Lobophytum*, with branching *Lithothamnion*. The *Lobophytum* stems are sub-cylindrical, the longest fragment measuring 57 millims. in length by 18 millims. in thickness; they are made up of robust, tuberculated, fusiform spicules, ranging up to 2 millims. in length by 0·5 millim. in thickness. The spicules are nearly in contact, but without definite arrangement. The stems are overgrown by several successive thin layers of *Lithothamnion*, which have probably tended to prevent their disintegration. The same kinds of foraminifera are present as in the preceding core, with the addition of *Nubecularia*. *Serpula*-tubes. Gastropod shells.

(4) [604–606]. Length 85 millims., width 102 millims. Cylindrical core, almost entirely of *Madrepora contecta*; the interstices of the corallum are now, to a large extent, filled up solid with sclerenchyma. Borings of *Cliona* in places. The coral is surrounded by a whitish hard sedimentary material, containing *Orbitolites*, *Haddonia*, *Spirorbis*, stellate spicules of *Leptoclinum* and *Lithothamnion*.

(5) [504, 505]. Length 114 millims. Core cylindrical; the central part of it consists of a large mass of *Astræa* sp., encrusted by *Polytrema planum* and thin layers of *Lithothamnion*, and these, in turn, are overgrown by an undetermined perforate coral. A thick wall-plate of *Heliopora cærulea*, perforated by *Cliona*. Fine-grained detrital material containing *Orbitolites complanata*, *Tinoporus baculatus*, *Gypsina inhærens*, *Polytrema miniaceum*, echinid spines, *Leptoclinum* spicules, Holothurian plates and branching *Lithothamnion*.

(6). Length 30 millims. A fragment of hard limestone with the same form of *Astræa* as in the preceding core. Nodular *Lithothamnion*.

(7). Length 108 millims. Cylindrical core of a grey, hard, cavernous limestone, composed of pieces of *Heliopora cærulea* and *Madrepora*, with a considerable amount of encrusting and branching *Lithothamnion*. At base of core a layer of foraminifera, chiefly belonging to *Tinoporus*, *Polytrema miniaceum*, and *Amphistegina*, partially cemented together. Echinid spines. *Serpula* and *Spirorbis*. Gastropods.

(8). Length 34 millims. Nodular lump of hard grey coral rock, consisting of *Heliopora cærulea*, *Porites*, *Lithothamnion* with foraminifera, filling the interspaces. Same forms as in preceding core with the addition of *Orbitolites*.

(9, 10, 11) [607]. Lengths 38, 30, 44 millims. Three nodular lumps of rock similar to preceding, consisting of *Heliopora cærulea*, much bored by *Cliona*, *Madrepora*, *Lithothamnion*, both encrusting and branching. *Polytrema miniaceum*. *Spirorbis*. Gastropod shells.

Depth from Surface, 10–20 *feet*; *Distance Bored*, 10 *feet*; *Total Length of Core Obtained*, 2 *feet* 5 *inches*; *Numbers of Cores*, 12–18.

Whitish grey, grey, and mottled limestone, hard, in part cavernous, in part massive, the higher cores mainly of corals; *Heliopora*, *Pocillopora* and *Madrepora*; the lower cores, Nos. 15 to 18, principally of branching *Lithothamnion* with *Polytrema planum*. The interspaces between the corals and between the branching *Lithothamnion* are filled in with whitish detrital sediment consisting of foraminifera, echinid spines, stellate spicules of ascidians, &c. This material in some places is consolidated into hard rock, in other places even in the same core, it is incoherent, loose and powdery. The corals, foraminifera and calcareous algæ retain their structures and are in the same condition of preservation as those nearer the surface, referred to above.

(3).—Detailed Notes on the Materials from the Main Boring.

Depth from Surface, 0–10 *feet; Distance Bored,* 10 *feet; Total Length of Core Obtained,* 2 *feet* 10 *inches; Numbers of Cores,* 1–11.

(*The figures between curved brackets give the number of the core, and those between square brackets the number of the microscopic slide.*)

The cores obtained in this first 10 feet from the surface are of a greyish-white, hard, partly cavernous limestone, with patches of a dirty greenish tint wherever *Heliopora* is present. They are principally of coral in cylindrical masses and irregular nodular lumps. The hollows between the corals are, in the cores from immediately below the surface, partly filled with the roots of plants and other vegetable *débris*, in the lower cores the interspaces are now either vacant, or filled with a fine detrital mud, either firmly cemented into a hard, dull, whitish rock, or as a loose, incoherent powder, which contains foraminifera, echinid spines, minute stellate spicules of ascidians, fragments of coral, gastropod shells, and pieces of encrusting and branching *Lithothamnion.*

The corals* present belong to *Millepora, Heliopora,* stems and detached spicules of alcyonaria, referred to the genus *Lobophytum, Astræa, Madrepora* and *Porites.* The structure in these corals is usually well preserved, but in many instances their interstices are now so infilled with a deposit of crystalline sclerenchyma and other materials, and further masked by a net work of tunnellings of sponges and other boring organisms, that it is difficult to make out their original characters. Not infrequently also, where the sedimentary calcareous mud has not penetrated into the interior of the corals, the interstices remain vacant or they are infilled with fine prismatic crystals of "conchite" or aragonite.

The length of the solid cores obtained (2 feet 10 inches) is somewhat less than one-third of the distance bored. The part of the boring not represented by the cores was composed, according to Professor David, chiefly of foraminifera, belonging to the genera *Orbitolites* and *Tinoporus.* Professor David considers that the materials from the surface to a depth of 3 feet below, represent a coral breccia, and the remaining 7 feet a raised reef, with patches of foraminifera and coral sand.

Details.

(1) [501]. Length 136 millims. Core cylindrical, consisting of irregular lumps of *Millepora nodosa, Heliopora cærulea,* and *Madrepora.* The corals are encrusted by layers of *Polytrema planum* and *Lithothamnion. Orbitolites marginalis, Polytrema miniaceum, Tinoporus baculatus,* and *Amphistegina Lessonii* are present. Echinid spines. Stellate ascidian spicules referred to *Leptoclinum.*

(2) [502]. Length 108 millims. Core cylindrical; about one-fifth of it consists of a mass of *Heliopora*

* As stated previously, I propose to include the Hydrocorallinæ and the Alcyonaria with the Madreporaria under the general term "Corals."

cærulea, with pieces of *Millepora nodosa* and *Madrepora*. The greater part of the core is a hard, grey detrital sediment, with numerous foraminifera, belonging to *Orbitolites*, *Tinoporus*, *Polytrema miniaceum*, *P. planum*, and *Amphistegina*. *Lithothamnion*. Gastropod shells.

(3) [503]. Length 120 millims. Core cylindrical, composed of lumps of *Millepora nodosa*, *Heliopora cærulea*, and pieces of Alcyonarian stems, referred to *Lobophytum*, with branching *Lithothamnion*. The *Lobophytum* stems are sub-cylindrical, the longest fragment measuring 57 millims. in length by 18 millims. in thickness; they are made up of robust, tuberculated, fusiform spicules, ranging up to 2 millims. in length by 0·5 millim. in thickness. The spicules are nearly in contact, but without definite arrangement. The stems are overgrown by several successive thin layers of *Lithothamnion*, which have probably tended to prevent their disintegration. The same kinds of foraminifera are present as in the preceding core, with the addition of *Nubecularia*. *Serpula*-tubes. Gastropod shells.

(4) [604–606]. Length 85 millims., width 102 millims. Cylindrical core, almost entirely of *Madrepora contecta*; the interstices of the corallum are now, to a large extent, filled up solid with sclerenchyma. Borings of *Cliona* in places. The coral is surrounded by a whitish hard sedimentary material, containing *Orbitolites*, *Haddonia*, *Spirorbis*, stellate spicules of *Leptoclinum* and *Lithothamnion*.

(5) [504, 505]. Length 114 millims. Core cylindrical; the central part of it consists of a large mass of *Astræa* sp., encrusted by *Polytrema planum* and thin layers of *Lithothamnion*, and these, in turn, are overgrown by an undetermined perforate coral. A thick wall-plate of *Heliopora cærulea*, perforated by *Cliona*. Fine-grained detrital material containing *Orbitolites complanata*, *Tinoporus baculatus*, *Gypsina inhærens*, *Polytrema miniaceum*, echinid spines, *Leptoclinum* spicules, Holothurian plates and branching *Lithothamnion*.

(6). Length 30 millims. A fragment of hard limestone with the same form of *Astræa* as in the preceding core. Nodular *Lithothamnion*.

(7). Length 108 millims. Cylindrical core of a grey, hard, cavernous limestone, composed of pieces of *Heliopora cærulea* and *Madrepora*, with a considerable amount of encrusting and branching *Lithothamnion*. At base of core a layer of foraminifera, chiefly belonging to *Tinoporus*, *Polytrema miniaceum*, and *Amphistegina*, partially cemented together. Echinid spines. *Serpula* and *Spirorbis*. Gastropods.

(8). Length 34 millims. Nodular lump of hard grey coral rock, consisting of *Heliopora cærulea*, *Porites*, *Lithothamnion* with foraminifera, filling the interspaces. Same forms as in preceding core with the addition of *Orbitolites*.

(9, 10, 11) [607]. Lengths 38, 30, 44 millims. Three nodular lumps of rock similar to preceding, consisting of *Heliopora cærulea*, much bored by *Cliona*, *Madrepora*, *Lithothamnion*, both encrusting and branching. *Polytrema miniaceum*. *Spirorbis*. Gastropod shells.

Depth from Surface, 10–20 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 2 *feet* 5 *inches; Numbers of Cores*, 12–18.

Whitish-grey, grey, and mottled limestone, hard, in part cavernous, in part massive, the higher cores mainly of corals; *Heliopora*, *Pocillopora* and *Madrepora*; the lower cores, Nos. 15–18, principally of branching *Lithothamnion* with *Polytrema planum*. The interspaces between the corals and between the branching *Lithothamnion* are filled in with whitish detrital sediment consisting of foraminifera, echinid spines, stellate spicules of ascidians, &c. This material in some places is consolidated into hard rock, in other places, even in the same core, it is incoherent, loose and powdery. The corals, foraminifera, and calcareous algæ retain their structures and are in the same condition of preservation as those nearer the surface, referred to above.

DETAILS.

(12). Length 55 millims. A nodular rock with cavernous hollows, consisting of a clump of *Pocillopora.* The corallites are for the most part filled up solid; the coral has been extensively tunnelled by boring organisms; some of the borings remain empty, others are infilled by fine detrital mud, now consolidated into hard rock. *Polytrema miniaceum*, *Lithothamnion*, with embedded orange-tinted tubes of *Serpula*.

(13) [506, 507, 608, 609]. Length 110 millims., diameter 100 millims. Cylindrical core nearly all of *Madrepora contecta*, the corallites of the branches and some of the cœnenchyma filled in with fine sediment, or with fibrous crystals of "conchite" or aragonite; other portions of the cœnenchyma remain empty. *Heliopora cærulea*, fragment. *Polytrema miniaceum*. *Lithothamnion*.

(14). About thirty irregular nodular fragments of hard, grey rock, worn by drill, the largest piece 50 millims., diameter 60 millims. Principally of corals: *Heliopora cærulea*, *Pocillipora* sp. with encrusting *Lithothamnion*.

(15, 15*bis*.). Length 205 millims., diameter 103 millims. Core cylindrical, for the most part a solid, compact, hard, mottled rock consisting of *Heliopora cærulea*, *Porites* (?), and *Lithothamnion*. Intermediate areas are filled in with fine detrital sediment containing *Polytrema miniaceum*, numerous echinid spines, some of large size and of purple colour, and tubes of *Serpula*. The sediment is now, for the most part, a hard rock, but in places it remains incoherent and powdery. Professor DAVID considers that this core is part of a coral reef platform formed at low-water level.

(16) [610]. Nodular fragments (22) of hard cavernous rock, principally of *Heliopora cærulea*, *Madrepora*, encrusting *Polytrema planum*, and *Lithothamnion*. *P. miniaceum* and *Carpenteria* also present. Largest fragment 50 millims. long by 65 millims. wide.

(17, 18). Length 275 millims., diameter 103 millims. Cores cylindrical, largely of branching *Lithothamnion*; the interspaces of fragmental materials and fine sediment, partly hardened into firm rock, partly as loose chalky powder. *Orbitolites*, *Polytrema miniaceum*, echinid spines, gastropod shells, small coprolitic pellets, orange-tinted tubes of *Serpula*.

Depth from Surface, 20–30 feet; Distance Bored, 10 feet; Total Length of Core Obtained, 3 feet 4 inches; Numbers of Cores, 19–33.

Whitish-grey, hard, cavernous limestone, mainly of thick plates of *Heliopora*, and undetermined perforate corals, with branching nodular and encrusting *Lithothamnion*, supplemented by the encrusting *Polytrema planum*. Interspaces between the corals are sometimes vacant, but more frequently filled with detrital calcareous mud, either consolidated into hard rock, or occasionally as an incoherent chalky powder. The foraminifera in this sediment include *Orbitolites*, *Placopsilina*, *Globigerina* (rarely) and *Polytrema miniaceum*. Other organisms present are detached stellate spicules of *Leptoclinum*, echinid spines, *Serpula*, gastropod shells, and, rarely, detached joints of *Halimeda*. Professor DAVID states that these cores certainly represent reef rock.

DETAILS.

(19). Length 100 millims. Rounded core, principally of branching and encrusting *Lithothamnion* with some small pieces of *Heliopora cærulea*, now in part bleached to a greyish tint. Irregularly laminated growths of an undetermined coral or hydrocoralline. Rock very cavernous, some of the vacant spaces may

have been originally filled with incoherent chalky mud, which has been washed away in the drilling and extraction of the core.

(20). Length 103 millims. Character similar to preceding, principally of branching and encrusting *Lithothamnion*. In the hardened calcareous mud *Polytrema miniaceum*, retaining the pinkish tint, also purple echinid spines.

(21, 22) [611]. Length 133 millims. Core cylindrical. The *Heliopora cærulea* is more prominent than the *Lithothamnion* in these cores. Its structure is well preserved, the tubes are partly empty, partly filled in with fine detrital mud. Laminate undetermined coral, the same as in core 19; its structure is masked by sclerenchyma and prisms of "conchite," and it is also extensively bored by algæ. The corals overgrown by *Lithothamnion* and *Polytrema planum*. In the consolidated mud *Orbitolites*, rarely; some detached 3-rayed spicules of calcisponges; *Leptoclinum* stellates, echinid spines, *Serpula*-tubes.

(23). Length 38 millims. Of the same materials as the preceding core; a commingling of *Heliopora cærulea* and *Lithothamnion*, with detrital mud containing echinid spines, *Polytrema*, coprolitic pellets, &c.

(24) [612, 613]. Length 120 millims. Core cylindrical, consisting of a very cavernous mass of *Heliopora cærulea*, an undetermined coral, *Polytrema planum* and *Lithothamnion*. Stellates of *Leptoclinum*, abundant in mud, echinid spines, *Carpenteria* and *P. miniaceum*. Professor DAVID states that this is an undoubted reef rock *in situ*.

(25). Length 69 millims. Like the preceding. The *Heliopora* is growing in thick upright laminæ, with the structure preserved; it is extensively tunnelled by *Cliona* sponges and other organisms. In the detrital calcareous mud there are large purple echinid spines and a few joints of *Halimeda*.

(26) [614]. Length 50 millims. Nodular lump, mainly of *Lithothamnion*, with some small pieces of *Heliopora cærulea*; encrusting *Polytrema planum* abundant, frequently alternating with *Lithothamnion*. Echinid spines, *Leptoclinum* spicules, *Orbitolites*, *Globigerina*, rare.

(27–31) [509, 615]. Rounded nodular pieces of core, with an aggregate length of 171 millims. Consisting of *Heliopora* and *Lithothamnion*, generally similar to the preceding. *Halimeda*, stellate spicules of *Leptoclinum*, minute fragments of *Heliopora*, &c., in the consolidated mud. *Placopsilina*.

(32) [508, 627]. Length 118 millims. Cylindrical core, consisting principally of a perforate coral, so infilled with sclerenchyma that it cannot be determined with certainty. It may possibly belong to *Madrepora*. The coral is overgrown by successive thin layers of *Lithothamnion*. Partially coherent foraminiferal and fragmental material, containing *Orbitolites*, *Polytrema miniaceum*, *Leptoclinum* stellates, and coprolitic pellets, surround the coral.

(33). Length 95 millims. Hard greyish, very cavernous core, consisting of *Heliopora cærulea*, an undetermined perforate coral, branching *Lithothamnion*, and echinid spines.

Depth from Surface, 30–40 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 4 *feet* 4 *inches; Numbers of Cores*, 34–55.

The cores are of whitish grey limestone, hard, cavernous to compact, mainly an agglomeration of corals and calcareous algæ, surrounded by fine sedimentary material with foraminifera, echinid spines, stellate spicules of ascidians, small fragments of corals, *Lithothamnion* and *Halimeda*. The principal corals are *Millepora*, *Heliopora*, *Pocillopora*, *Stylophora*, *Madrepora*, and *Montipora*. The corals retain their structure, but they are largely perforated by boring organisms, and the interspaces are mostly infilled with sclerenchyma or with prisms of "conchite," which mask their characters. The foraminifera belong to *Orbitolites*, *Placopsilina*, *Discorbina*, *Carpenteria*, and

apparently in position of growth. The interspaces of the cœnenchyma in this specimen as well as the corallites of the branches are largely infilled with sclerenchyma or sediment.

Depth from Surface, 40–50 feet; Distance Bored, 10 feet; Total Length of Core Obtained, 1 foot 1 inch; Numbers of Cores, 56–59.

The only cores obtained from this 10 feet of the bore consist of irregular fragments of whitish-grey, hard, coral rock, and massive blocks of *Madrepora contecta*, in the same condition of preservation as those previously referred to (Cores 13, 52). Other corals present belong to *Stylophora* and *Pocillopora*. Detached spicules of alcyonaria, echinid spines, *Serpula*, *Spirorbis*, *Polytrema miniaceum*, *Lithothamnion*, branching and encrusting.

DETAILS.

(56). Length 40 millims. An irregular fragment, consisting of pieces of coral and other organisms agglomerated together. *Stylophora*, *Pocillopora*, alcyonarian spicules, echinid spines, plates of *Cidaris*, *Serpula*, *Spirorbis*, *P. miniaceum*. Branching and encrusting *Lithothamnion*.

(57). Length 66 millims. Fragments of rock with *Stylophora*, echinid spines, &c.

(58). Length 87 millims., diameter 103 millims. A block of *Madrepora contecta*, with the interspaces largely filled up with sclerenchyma and carbonate of lime. The upper and under portions of this block show eroded and pitted surfaces to which *Spirorbis* and *Carpenteria monticularis* are attached.

(59). Length 138 millims., diameter 102 millims. Massive cylindrical core of *Madrepora contecta*. The cœnenchymal interspaces of the interior of the coral are for the most part empty. The upper surface is uneven and covered with small pits, the work probably of boring organisms, and in these numerous individuals of a small *Spirorbis* are fixed. The direction of the branches indicate that the coral is in its position of growth.

Depth from Surface, 50–60 feet; Distance Bored, 10 feet; Total Length of Core Obtained, 1 foot 2 inches; Numbers of Cores, 60–67.

The cores consist of nodular lumps of cream-coloured, hard, dense coral rock, mostly so infilled with sclerenchyma and other materials that the character of the organisms is obscured; *Astræa*, *Madrepora*, and *Montipora* (?) are present. Stellate spicules of *Leptoclinum*, *Carpenteria*, and *Gypsina*. Encrusting *Lithothamnion*.

DETAILS.

(60) [511, 512]. Length 62 millims. A lump of *Madrepora contecta* (?), the structure nearly entirely concealed.

(61) Length 35 millims. A flattened lump of *Madrepora* sp., the coral now filled in nearly solid. A central cavity, probably a boring, filled in with white incoherent powder. Lower surface with pittings and *Spirorbis*. *Polytrema miniaceum*.

(62) [628]. Length 40 millims. A solid lump of *Madrepora* encrusted by successive thin layers of *Lithothamnion*. The coral interspaces partly filled with prisms of "conchite," partly with fine consolidated sediment containing *Leptoclinum* stellates, *Carpenteria* and *Gypsina*. The minute structure of the coral is preserved, also the delicate ramifications of boring algæ.

(63). Length 35 millims. A rounded nodule of an obscure coral, probably *Montipora*.

(64) [620]. Length 35 millims. A rounded nodule of *Astræa* sp. The minute structure shown in the

microscopic section. The corallites are in part empty, in part lined by radiating acicular crystals. The borings in the coral infilled with fine, hard, granular sediment containing stellates of *Leptoclinum*.

(65). Length 73 millims. An irregular nodular mass of *Madrepora contecta*, having the interspaces, for the most part, solidly infilled. The surface in part pitted, with attached *Spirorbis* and cheilostomatous polyzoa.

(66). Length 23 millims. A small compact nodule, probably of *Madrepora*.

(67) [621]. Length 40 millims. A nodular mass of *Madrepora*, the interspaces of the coral nearly filled in solid with sclerenchyma.

Depth from Surface, 60–70 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 2 *feet* 2 *inches; Numbers of Cores*, 68–84.

The cores for the most part are nodular masses of whitish-grey, or cream-coloured, dense, hard, coral limestone, either nearly compact or minutely porous. The corals are almost entirely of *Madrepora*, with a single piece of *Heliopora cærulea*. In some of the coral lumps a portion of the surface is pitted by boring organisms. Some incoherent fragmental materials produced by the action of the drill have been obtained from the depths of 65 and 70 feet from the surface. They consist principally of foraminifera, small angular pieces of broken coral, alcyonarian spicules, echinid spines, polyzoa, *Lithothamnion* and *Halimeda*. Of less common occurrence are detached spicules of calcisponges, joints of corallines, entomostraca, small claws of crustaceans, stellates of *Leptoclinum*, and small gastropods. The detached valves of a brachiopod, *Thecidea maxilla*, HEDLEY, also occur. The most common foraminifera are *Amphistegina Lessonii* and *Heterostegina depressa*; Mr. CHAPMAN has determined several other forms, a list of which is given below. All the organisms are very fresh looking.

DETAILS.

(68) [622, 623]. Length 42 millims. A rounded nodule of *Madrepora*, the interstices largely infilled with sclerenchyma. The coral is encrusted by delicate layers of *Lithothamnion*, alternating with layers of *Polytrema planum*. Borings infilled with fine sediment containing stellates of *Leptoclinum*, *P. miniaceum*, *Carpenteria* and *Serpula* tubes.

(69). Length 32 millims. A nodular lump of *Madrepora contecta*, the interior so infilled with solid sclerenchyma as to be scarcely recognisable. In a small cavity, polyzoa, lamellibranch shell and *Serpula*.

(70–73). Irregular nodular lumps of hard, cream-tinted rock, partly worn by drill, having a total length of 136 millims. Surfaces pitted in places, with *Spirorbis* attached. The rock composed of *Madrepora contecta*, the coral interspaces filled in solid with sclerenchyma, &c. Some portions extensively bored by *Cliona*, the tunnelling now filled with fine hardened mud. *Polytrema miniaceum*, *Lithothamnion*.

(74). Length 50 millims. Piece of cylindrical core of hard dense rock; nearly entirely of *Madrepora contecta*, in the same condition as the preceding. The upper surface is overgrown by *Lithothamnion* and on this *Porites* is attached. The lower surface is pitted, and a few examples of *Spirorbis* are growing on it.

(74). From the same depth, 65 feet, as the solid coral and bearing the same number (74), a box of fragmental materials consisting of loose angular particles of the same cream-tinted coral rock as the solid cores. These evidently have been produced by the action of the drill in the process of boring, the coral structure can be recognised in many of the small pieces. Mingled with the coral fragments are other microscopic organisms in considerable variety, having a fresh, unworn appearance, many of them are fractured, but they have not been rounded. Mr. F. CHAPMAN gives the following list of the foraminifera: *Miliolina*

subrotunda, *Orbitolites complanata*, *O. marginalis*, *Textularia sagittula*, var. *fistulosa*, *Cristellaria articulata*, *Sagrina raphanus*, *Spirillina vivipara*, *Spirillina*, sp. nov., *Discorbina patelliformis*, *Discorbina*, sp. nov., *Truncatulina rostrata*, *Gypsina vesicularis*, *Polytrema miniaceum*, also var. *alba*, *Amphistegina Lessonii*, *Heterostegina depressa*. With the exception of the two last-named species, which are very common, the forms are rare, and the majority are only represented by single specimens.

Alcyonarian spicules are very abundant. They are detached, varied in size, strongly tuberculate, and probably belong to the genus *Lobophytum*. Echinid spines are abundant and well preserved as regards their structure, but for the most part they are only fragments. Detached test plates of *Cidaris* are present, also portions of the dental apparatus of echinids. There are a few fragmentary three-rayed calcisponge spicules, but no spicules of siliceous sponges have been met with. Entomostraca are represented by a few valves of a species of *Bairdia*.

Claws of small crustaceans occur, but they are not common. Minute fragments of polyzoa are numerous, also the minute stellate ascidian spicules referred to *Leptoclinum*. *Thecidea maxilla*. Small forms of gastropod shells and detached opercula, are fairly plentiful, the shells range in length from 0·7 millim. to 2·5 millims. and in greatest width from 0·25 millim. to 1·5 millims. Mr. EDGAR A. SMITH, of the British Natural History Museum, has recognised the following genera: *Cerithium*, *Triforis*, *Marginella*, *Leptothyris* (opercula only), *Cyclostrema* and *Rissoina*. Small ovoid pellets, probably coprolitic in character, are very numerous. Detached joints of *Halimeda*, also joints of corallines, either singly or three or four in connection, are of common occurrence.

(75, 76). Two irregular pieces of hard coral rock, together 76 millims. in length, of *Madrepora contecta* and an undetermined coral. The corals mostly infilled solid with sclerenchyma, &c., and partly overgrown with *Lithothamnion*.

(77). Length 30 millims. An irregular nodular fragment, worn by drill, of *Heliopora cærulea*, encrusted by successive layers of *Lithothamnion*. The coral is of a dirty green colour, and the tubes are now solidly infilled with sclerenchyma.

(78). Length 101 millims., width 77 millims. A cylindrical core of *Madrepora contecta*. The coral somewhat cavernous where excavated by boring organisms, in places also encrusted by *Lithothamnion*.

(79, 80, 81). Length 66 millims. altogether. Irregular fragments of hard coral rock consisting of *Madrepora* and of an undetermined perforate coral encrusted by *Lithothamnion*.

(82). Length 65 millims. Hard nodular mass of *Madrepora contecta*, mostly infilled solid. In places bored by *Cliona*. Parts of surface unevenly pitted and with minute *Spirorbis* attached.

(83) [513]. Length 50 millims. A nodular mass of *M. contecta* similar to the preceding; overgrown in places by *Lithothamnion*. The coral structure is well preserved, as seen in section under the microscope; the interspaces are partly empty, partly filled with prisms of "conchite."

(84). At 70 feet. Fragmental materials coarse and fine, the greater part angular chips or fragments of hard grey coral rock broken up by drill. Mingled with these there are a few foraminifera, alcyonarian spicules, echinid spines, opercula of gastropods, coprolitic pellets, and joints of corallines. The foraminifera, as determined by Mr. CHAPMAN, are: *Spirillina* sp., nov., *Pulvinulina repanda*, *Gypsina globulus*, one specimen each, *Polytrema miniaceum*, also var. *alba*, *Amphistegina Lessonii* and *Heterostegina depressa*, common.

Depth from Surface, 70–80 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 1 *foot* 1 *inch; Numbers of Cores*, 85–93.

The only solid cores in the 10 feet are irregular nodular fragments of hard, whitish-grey, or cream-tinted limestone, technically termed "knoblings"; they are rounded to some extent by the drill. These nodules are almost entirely of *Madrepora contecta*, in the same condition of preservation as the specimens in the cores above. With the

Madrepora, *Porites* occasionally occurs. The corals are in places overgrown by *Lithothamnion* and *Polytrema planum*; *P. miniaceum*, retaining its pink tint, likewise occurs. The coral lumps taken together are but little over 1 foot in length; the remaining 9 feet are only represented by small angular fragments of coral, broken up and triturated by the drill, commingled with foraminifera, spicules of alcyonaria, branching glassy fragments of polyzoa, echinid spines, small gastropods, coprolitic pellets, joints of *Halimeda*, and corallines. The organisms are all in good preservation.

DETAILS.

(85-87) [624]. Total length 114 millims. Four nodular lumps of coral rock consisting of the common *Madrepora contecta*. The structure is preserved, the interstices are largely filled with sclerenchyma, in some parts the coral is tunnelled by boring organisms, and the tunnels are now packed with hard granular sediment containing minute pieces of coral and stellate ascidian spicules. The coral is overgrown by alternate layers of finely laminate *Lithothamnion* and *Polytrema planum*. *Orbitolites*, *Carpenteria*, and *Amphistegina*.

(88) [625]. Length 62 millims. A nodular piece of *Madrepora contecta*, the structure well shown in microscopic section; it is apparently unaltered; the interstices of the cœnenchyma are empty, or lined with prismatic crystals of "conchite."

(89) [626]. Length 40 millims. Irregular nodule of hard whitish rock, consisting of a piece of perforate coral, possibly *Porites*, thickly encrusted by alternate laminæ of *Lithothamnion* and *Polytrema planum*. The laminæ of the *Lithothamnion* do not fit evenly over the substratum, but leave interspaces, filled in with fine sediment, largely consisting of stellate ascidian spicules, probably belonging to *Leptoclinum*. *Gypsina*, *Amphistegina Lessonii*, and *Heterostegina depressa*.

(90). At 75 feet. Fine-grained fragmental materials, consisting largely of angular fragments of coral rock, and of fresh looking pieces of coral with the interstices empty. The following foraminifera have been determined by Mr. CHAPMAN:—*Orbitolites complanata*, rare; *O. marginalis*, frequent; *Carpenteria balaniformis*, rare; *Polytrema miniaceum*, frequent; var. *alba*, one specimen; *Amphistegina Lessonii* and *Heterostegina depressa*, both species very abundant. Detached 4-rayed spicules of calcisponges; alcyonarian spicules, abundant; small fragments of *Stylaster*, sp.; entire and fragmentary spines, detached test-plates and teeth of echinids; entomostraca, rare; claws of small crustaceans; *Spirorbis*; branching fragments of polyzoa; minute lamellibranch shells; shells and opercula of small gastropods, determined by Mr. EDGAR A. SMITH to belong to the following genera:—*Cæcum*, *Leptothyris* (only opercula), *Triforis*, *Marginella*, *Rissoa*, *Phasianella*, *Columbella* and *Atlanta*. The smallest of these shells is 0·75 millim. in length by 0·25 millim. in breadth, and the largest 2·5 millims. by 1·25 millims. Coprolitic pellets are very common. This detrital material is very similar in character to that from Core 74 above.

(91, 92) [629]. Length 124 millims. Two irregular nodules of *Madrepora contecta*, the structure well preserved, the coral interstices nearly filled up solid with sclerenchyma. Surfaces overgrown with thin laminate *Lithothamnion*. *Carpenteria* present. Borings in the *Lithothamnion* filled up with fine hardened sediment containing stellate spicules of *Leptoclinum*.

(93). Length 53 millims. by 87 millims. in breadth. An irregular nodule of *Madrepora contecta*, the cœnenchymal interstices largely vacant.

Depth from Surface, 80–90 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 1 *foot* 4 *inches; Numbers of Cores*, 94–100.

The solid cores obtained are cylindrical or nodular lumps of whitish-grey and cream-coloured limestone, with some nodules of dirty-green *Heliopora* rock. The

2 D 2

upper cores are of the same kind of hard, mostly compact, coral rock which extends from the surface to the depth of about 84 feet, below this the rock is more of a porous character and softer so as to be more readily scratched by a knife. The solid cores are almost entirely of corals belonging to *Heliopora cærulea*, *Pocillopora*, *Orbicella*, *Madrepora*, *Porites* and *Astræopora*. The coral structures are preserved; the coral interstices are either empty or partly filled with radiating crystals of "conchite." The spaces between the branches of the *Pocillopora* are infilled with calcareous sediment containing numerous foraminifera and fragments of *Lithothamnion* and *Halimeda*. According to Professor DAVID, the part of the section not represented in the cores consists of fine rubble and "sand" (detritus of calcareous organisms).

DETAILS.

(94). Length 150 millims., by 81 millims. in diameter. A solid cylindrical core, nearly entirely of *Madrepora* sp., growing over a fragment of *Porites*. The corallites mostly infilled with sclerenchyma.

(95). Length 42 millims. A rounded nodule of compact hard rock, consisting of several successive explanate layers of a perforate coral, (?) *Porites*. The coral is encrusted with *Lithothamnion* and perforated by *Cliona*.

(96) [514]. Length 33 millims. A fragment of whitish porous rock, consisting of *Orbicella* sp. The coral interspaces either empty, partially filled with fine sediment, or with radiating prisms of "conchite." *Amphistegina*.

(97, 98). Two nodular lumps of *Heliopora cærulea*, one 60 millims. by 50 millims., the other 75 millims. by 50 millims. The structure well shown; the tubes for the most part empty and unaltered. The outer surface pitted by boring organisms, *Serpula* attached. Also partly encrusted by *Lithothamnion*, and to this orange-tinted annelid tubes are affixed.

(99). Length 37 millims. A cylindrical core of white, porous, fairly hard rock, consisting of *Astræopora*; the corallites are, in part, filled with sediment, in part empty.

(100) [515]. Length 75 millims. by 80 millims. in diameter. Rock similar to preceding; the core consists of a clump of closely arranged, branching, *Pocillopora*, apparently near to *P. glomerata*, GARDINER. The structure fairly well preserved, the corallites either empty or infilled with sediment or radiating crystals of "conchite." The sediment filling the spaces between the branches of the coral contains the following foraminifera, determined by Mr. CHAPMAN:—*Miliolina*, *Orbitolites*, *Globigerina* (rare), *Rotalia* (?), *Truncatulina*, *Carpenteria*, *Polytrema planum*, *Gypsina*, *Amphistegina* and *Heterostegina*. *Lithothamnion* and joints of *Halimeda* also occur.

Depth from Surface, 90–100 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 1 *foot* 1 *inch; Numbers of Cores*, 101–108.

The only pieces of solid cores from this 10 feet of the boring are six small irregular lumps of porous whitish limestone, consisting of corals, including *Pocillopora*, *Orbicella*, and *Porites*. These corals retain their structures in good preservation. Nine feet of the boring are only represented by detrital materials, mainly triturated fragments of hard coral rock with detached foraminifera, spicules of alcyonaria, echinid spines, and joints of *Halimeda*.

DETAILS.

(101). Length 63 millims. Cylindrical core, principally of a nodular lump of *Porites* inclosed in a mass of lightly cemented fragmental material, mainly of alcyonarian spicules, *Amphistegina*, &c.

(102). Sample of finely granular detrital materials consisting principally of small angular chips of coral rock, triturated by the drill; amongst these *Heliopora cœrulea* and perforate coral structure can be recognised with a lens; the foraminifera include *Orbitolites complanata*, *Tinoporus baculatus*, *Amphistegina Lessonii* and *Heterostegina depressa*. Alcyonarian spicules, echinid spines, and *Halimeda*.

(103, 104). Total length 105 millims. Two irregular nodular lumps of *Pocillopora* sp., similar to the form in Core 100, showing in places the surface characters of the coral. Numerous joints of *Halimeda* are cemented to the coral.

(105) [630]. Length 35 millims. A nodular lump of *Orbicella heliopora*. The structure of the corallum is fairly well preserved, the interstices, in part empty, in part infilled with radiating crystals of "conchite," calcite, or with white hardened mud, containing stellate spicules of *Leptoclinum*.

(106). Length 30 millims. An irregular fragment of *Pocillopora*.

(107). Length 23 millims. A small nodule of hard white coral rock, showing perforate structure, probably *Porites*.

(108). Sample of granular fragmental material, similar to that of Core No. 102. The angular chips appear to be mainly of coral rock, pieces of *Heliopora cœrulea* are present. Of the foraminifera, Mr. CHAPMAN has determined, *Miliolina circularis*, one specimen, *Polytrema miniaceum*, rare, *Amphistegina Lessonii*, *Heterostegina depressa*. Also alcyonarian spicules and echinid spines.

Depth from Surface, 100–110 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 7 *inches; Numbers of Cores*, 109–115.

The solid cores in this 10 feet of the boring are only represented by a few rounded fragments of whitish or cream-coloured limestone, with a total length of 7 inches. These fragments are principally of corals: *Pocillopora*, *Fungia* (?), *Astræa*, *Madrepora*, and *Montipora*. The coral structure is preserved. One piece of the rock is of fine organic sediment with foraminifera, *Leptoclinum* stellates, &c., cemented into hard rock by calcite and prismatic crystals of "conchite." The greater part of the core, as shown by samples, consists of coral rock now broken up into minute fragments by the drill, with a small proportion of foraminifera, alcyonarian spicules, echinid spines, &c. In one sample minute chips of the greenish *Heliopora cœrulea* are present.

DETAILS.

(109). Sample of loose materials, mainly small angular chips of coral rock, often stained a rusty tint by the iron of the drilling apparatus; some chips of *Heliopora*, *Amphistegina Lessonii*, echinid spines and alcyonarian spicules.

(110) [516, 517]. Length 32 millims. by 48 millims. A rounded irregular nodule of fairly hard white rock with roughened surface; it is composed of detrital mud with numerous foraminifera, a fragment of *Fungia* (?) and other organisms. The foraminifera include *Orbitolites*, *Carpenteria*, *Polytrema planum*, *Gypsina*, and *Amphistegina*. *Spirorbis*, stellates of *Leptoclinum*, *Lithothamnion*.

(111) [518]. Length 33 millims., breadth 22 millims. A small round nodule of hard white coral, apparently a piece of *Astræa*, with the minute structure well shown. The septal interspaces lined with prismatic crystals of "conchite," or partly filled with calcite and detrital sediment.

(112). Length 66 millims. A cylindrical core mainly of a massive *Madrepora*, the corallites largely infilled with sclerenchyma, &c. At base, detrital mud with *Amphistegina*, now cemented into hard white rock.

(113). Length 23 millims. A nodule of hard greyish rock consisting of branching *Pocillopora*. The corallites for the most part solidly infilled with sclerenchyma, &c.

(114) [519]. Length 26 millims. A nodular lump of hard rock consisting of *Montipora*. The interseptal spaces almost entirely filled up with prismatic crystals of "conchite." Hardened detrital mud attached to the coral contains *Orbitolites*, *Carpenteria*, stellate spicules of *Leptoclinum*, and fragments of *Lithothamnion*.

(115). Sample of loose detrital materials, principally minute angular chips of coral rock, like those in No. 109. *Amphistegina*, alcyonarian spicules.

Depth from Surface, 110–120 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 8 *inches; Numbers of Cores*, 116–120.

The solid cores consist of five partly cylindrical lumps of hard, whitish or cream-coloured limestone altogether only 8 inches in length. Three of these pieces are of *Madrepora contecta*; the structure of the coral is well preserved, the interspaces are either empty or infilled in varying degrees with sclerenchyma or radiating prismatic crystals. The two other pieces of core consist of *Montipora* and a thick mass of *Millepora nodosa*, in good preservation. The materials composing the rest of the boring are presumably rubbly rocks, ground up fine by the drill; samples from the middle and lower portions of this 10 feet of the boring are similar to those described above; they consist mainly of little angular chips of rock with a small proportion of foraminifera, alcyonarian spicules, gastropoda, claws of small crustacea, joints of *Halimeda*, &c.

DETAILS.

(116). Length 83 millims. Rounded core of *Madrepora contecta*. The cœnenchymal interstices for the most part empty, as in recent specimens.

(117) [631]. Length 50 millims. Cylindrical core of the same coral as the preceding. In places it is penetrated by borings of *Lithodomus*.

(118). Sample of fine granular material from the boring, principally of angular chips of rock; small solidified casts of the corallites of *Pocillopora* can be distinguished. *Amphistegina Lessonii*, not uncommon. Alcyonarian spicules, polyzoa, gastropoda. *Halimeda*.

(119). Length 25 millims. A cylindrical core of *Montipora* sp., in places penetrated by annelid tubes and bored by *Cliona*.

(120). Length 50 millims. A rounded core of *Millepora nodosa*; the interstices of the skeleton in the interior of the corallum, for the most part not infilled. *Serpula*-tubes.

(120). Sample of granular material, principally of angular chips of rock with some *Amphistegina Lessonii* and alcyonarian spicules.

Depth from Surface, 120–130 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 2 *feet* 4 *inches; Numbers of Cores*, 121–129.

About one-fourth of this 10 feet of the boring consists of solid, massive, cylindrical cores of greyish-white or cream-tinted limestone, mainly of corals, with a considerable admixture of fragmental and foraminiferal material filling up the interspaces between them; the material is cemented into hard rock. The corals belong to *Millepora*,

Pocillopora, and *Madrepora*. *Pocillopora* is very abundant, it forms the main constituent through several consecutive cores with a total length of 16 inches, and is apparently in the position of growth. The coral has the minute structure preserved, the interspaces are either empty or lined with prismatic crystals of "conchite," or partly with calcite and fine sediment. The corals are frequently encrusted by *Polytrema planum*. *Lithothamnion* is also present. *Amphistegina Lessonii* is very abundant, *Tinoporus baculatus*, and *Carpenteria*. A sample of loose material from the lower portion of this part of the core contains angular fragments of hard rock with some foraminifera, echinid spines, &c.

DETAILS.

(121). Length 144 millims. Massive cylindrical core 80 millims. in diameter, consisting of a thick layer of *Madrepora* sp., with branching *Pocillopora* and *Millepora*. Between the corals fragmental materials with *Orbitolites*, *Amphistegina*, purple echinid spines, *Serpula*, *Lithothamnion*.

(122). Length 80 millims. Cylindrical core generally similar to preceding, of *Pocillopora* and *Madrepora*, with a considerable amount of cemented fragmental and foraminiferal rock, *Amphistegina*, *Lithothamnion*.

(123) [632]. Length 100 millims. Cylindrical core with *Millepora*, *Pocillopora* and *Madrepora*. The minute structure of the *Pocillopora* shown in thin section; the borings in the coral mostly infilled with granular mud containing stellate ascidian spicules; the coral is partly overgrown with a thick layer of *Polytrema planum*. Other foraminifera present are *Amphistegina*, *Tinoporus* and *Carpenteria*. Echinid spines.

(124) [633]. Length 70 millims. Cylindrical core, of hard, compact to porous, rock, principally of *Pocillopora* with a piece of *Madrepora conferta*. In fragmental mud same foraminifera as in No. 123. Gastropod shell.

(125). Length 75 millims. Hard, somewhat porous limestone, due to the empty interstices of the corals. Largely of *Pocillopora*, with some *Millepora* and *Madrepora*. *Amphistegina*, echinid spines, *Lithothamnion*.

(126). Length 50 millims. Cylindrical core, principally of *Pocillopora* in fragmental material, with *Amphistegina* and *Tinoporus baculatus*.

(127). Length 70 millims. Cylindrical core, like the preceding, mainly of *Pocillopora*, also with a piece of branching *Madrepora*. Consolidated detrital mud with *Orbitolites* and *Amphistegina*.

(128). Length 100 millims. Cylindrical core, cavernous on outer surface where imperfectly cemented, fragmental materials having been washed away. Principally of *Pocillopora*, apparently belonging to the same species as that in the preceding cores, 121–127. Fragmental materials with *Amphistegina*, echinid spines, *Serpula*, gastropod shell, *Lithothamnion*, encrusting; also in thick laminæ.

(129). Sample of finely ground-up materials, mainly of angular chips of rock, with a few foraminifera principally *Amphistegina Lessonii*; *Spiroloculina grata*, one specimen, determined by Mr. CHAPMAN. Small gastropod, echinid spines.

Depth from Surface, 130–140 *feet*; *Distance Bored*, 10 *feet*; *Total Length of Core Obtained*, 1 *foot*; *Numbers of Cores*, 130–134.

Two pieces of cylindrical cores and four fragments, with a total length of 1 foot, represent the solid cores from this 10 feet of the boring. The cores are of hard

greyish-white limestone, and consist principally of *Madrepora* with the interstices of the coral filled up solid, and some pieces of *Pocillopora*. Some of the smaller pieces of rock are of consolidated foraminifera and fragmental materials, including alcyonarian spicules, stellate spicules of ascidians, and *Lithothamnion*. The foraminifera belong principally to *Orbitolites*, *Carpenteria*, *Polytrema*, *Tinoporus* and *Amphistegina*. The sample of fine grained material consists, as usual, largely of angular chips of whitish rock with a few scattered specimens of foraminifera, frequently fragmentary; they include *Gypsina vesicularis*, *Nonionina umbilicata* and *Amphistegina Lessonii*.

DETAILS.

(130). Length 127 millims. Cylindrical core principally of a massive *Madrepora*, the corallites mostly filled up with sclerenchyma. *Pocillopora*. Consolidated fragmental material with foraminifera and polyzoa.

(131). Three rolled nodular pieces of core, with a total length of 73 millims., consisting of fragments of *Madrepora* similar to the preceding.

(132) [634]. Length 32 millims. An irregular flattened piece of hard rock consisting of consolidated fragmental materials with an Astræan coral, a fragment of alcyonarian stem referred to *Lobophytum*, numerous foraminifera, mentioned above, stellate spicules of *Leptoclinum* and gastropoda. Nodose *Lithothamnion*. The spicules of *Lobophytum*, viewed in transverse sections under the microscope, have a very similar appearance to fibrous radiating oolitic grains; they show delicate fibres radiating from an axial line, and sometimes concentric growth lines. The spaces between the spicules are filled with fine sediment. The fragmental materials are cemented together by calcite.

(133) [635]. Length 75 millims. Cylindrical core of hard grey rock, consisting of *Madrepora*. The coral interstices partially filled with sclerenchyma, the borings in it with fine mud or radiating prisms of "conchite." *Polytrema planum* partly overgrows the coral. *Orbitolites*.

(134). Sample of loose fragmental materials, with foraminifera, also with alcyonarian spicules, echinid spines, polyzoa, and small ovoid coprolitic pellets.

Depth from Surface, 140–150 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 5 *inches; Numbers of Cores*, 135–137.

The only solid cores from this 10 feet of the boring are three rounded pieces of grey, dense, hard, coral rock, apparently *Madrepora* sp. The remaining 9 feet 7 inches of the boring consists, according to Professor DAVID, of "sand" or fine rubble.

DETAILS.

(135) [636]. Length 55 millims. Rounded core of *Madrepora* sp. similar to that in Core 133. The interstices of the coral are for the most part infilled with sclerenchyma, calcite, or prisms of "conchite." Coral partly overgrown with *Polytrema planum*. *Carpenteria* and *Amphistegina* present.

(136) [637]. Length 32 millims. A nodular piece of the same coral as the preceding.

(137) [638]. Length 33 millims. A cylindrical core of the same *Madrepora* as the two preceding, and in the same state of preservation.

Depth from Surface, 150–160 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 5 *inches; Numbers of Cores*, 138–141.

The solid cores of this 10 feet of the boring are represented by a cylindrical mass and two rounded nodules of hard greyish-white limestone, having a total length of 5 inches. In contrast with the large majority of the solid cores hitherto met with, which have been principally of corals, these cores are of consolidated fragmental materials with numerous foraminifera and also detached joints of *Halimeda*. The organisms are well preserved and are cemented together by calcite. A sample of loose materials from this depth consists of the usual angular fragments of whitish rock with a few foraminifera.

DETAILS.

(138). Sample of fragmental materials containing *Amphistegina Lessonii*, *Tinoporus baculatus* and alcyonarian spicules.

(139, 140). Two nodular pieces of hard white rock, with a total length of 54 millims. Apparently of consolidated fragmental materials, but their character is not distinguishable without a microscopic section.

(141) [520, 521, 522]. Length 80 millims. by 80 millims. in diameter. Cylindrical core, of dense rock with a few small cavities. Of fragmental materials and foraminifera, belonging to *Orbitolites*, *Textularia rugosa*, *Truncatulina*, *Planorbulina*, *Discorbina*, *Cristellaria*, *Globigerina*, *Carpenteria*, *Polytrema*, *Gypsina*, *Amphistegina* and *Heterostegina*. *Halimeda* abundant. Stellate spicules of *Leptoclinum*.

Depth from Surface, 160–170 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 0; *Numbers of Cores*, 142, 143.

No solid cores were obtained from this 10 feet of the boring, only loose fragmental materials, two samples of which are referred to below.

DETAILS.

(142). Fine whitish powdery material of sub-angular and rounded grains, with *Tinoporus baculatus*, *Amphistegina Lessonii*, alcyonarian spicules, polyzoa, and *Serpula* tubes.

(143) [849]. Coarse-grained rock fragments, mostly stained a reddish tint, due to the iron of the drilling apparatus. A large majority of the grains are angular chips or splinters of rock; the organisms are often fractured and have lost their fresh appearance. The commonest forms are *Amphistegina* and alcyonarian spicules. The latter are in process of decay. The tubercles have mostly disappeared and the surfaces are now of powdery material. Other foraminifera determined by Mr. CHAPMAN are *Anomalina polymorpha*, *Tinoporus baculatus*, *Gypsina* sp. nov., *G. vesicularis*, *Polytrema miniaceum*, and *Carpenteria*. Casts of fragments of *Millepora* and *Pocillopora*, and pieces of perforate corals. Polyzoa, ostracoda, echinid spines, rare, and broken joints of *Halimeda*. Small pieces of the cementing calcite are still attached to some of the organisms.

Depth from Surface, 170–180 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 1 *foot* 4 *inches; Numbers of Cores*, 144–150.

The solid cores are cylindrical or irregular nodules of greyish-white, hard, somewhat porous or slightly cavernous limestone, principally of foraminiferal and

fragmental materials. Pieces of *Madrepora* and *Porites*, also of alcyonaria are present, which are consolidated with the smaller organisms by calcite. The remainder of this 10 feet of core consists, according to Professor DAVID, of "sand" or "coral" rubble.

DETAILS.

(144) [523, 524, 639]. Length 85 millims. Cylindrical core, slightly cavernous, where the fragmenta materials have not been consolidated. Microscopic sections show that the rock is composed of foraminifera and other organic fragments. The foraminifera belong to *Orbitolites*, *Discorbina*, *Textularia*, *Truncatulina*, *Carpenteria*, *Globigerina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. They are in good preservation and their minute structure is distinctly shown under the microscope. Echinid spines numerous. Branching and encrusting *Lithothamnion*, *Halimeda* joints.

(145) [640]. Length 100 millims. Cylindrical, somewhat porous in places. With the exception of a nodular piece of *Porites*, encrusted by *Lithothamnion*, the rock is foraminiferal, similar to the preceding. Alcyonarian spicules, echinid spines, small gastropod. *Halimeda*.

(146) [641]. Length 40 millims. A nodular lump of cream-coloured rock, rounded by drill, porous. A thin section under the microscope shows that it is a mass of alcyonarian spicules, probably a portion of a stem of *Lobophytum*. The spicules are partially decayed, the interspaces are filled by calcite. *Amphistegina*.

(147). Length 55 millims. Cylindrical, cavernous, also with small holes where organic fragments have been dissolved out. Apparently fragmental, the only organisms recognisable by a lens are echinid spines and *Amphistegina*.

(148). Length 60 millims. Rounded core of dense greyish rock, apparently *Madrepora*; structure indistinct.

(149, 150). Length 55 millims. Two nodular pieces of porous rock, apparently fragmental, similar to No. 147.

Depth from Surface, 180–190 *feet*; *Distance Bored*, 10 *feet*; *Total Length of Core Obtained*, 1 *foot* 2 *inches*; *Numbers of Cores*, 151–158.

The solid cores are for the most part small rounded pieces, but in two instances they are cylindrical. The rock is greyish-white limestone, moderately hard, cavernous, where fragmental materials have not been consolidated, and distinctly porous, with numerous small holes, frequently with the definite outlines of some organism which has been dissolved away. One small piece of core consists of the stem of an alcyonarian, probably *Lobophytum*, the remainder apparently are mainly composed of foraminifera and fragments of organisms, consolidated by calcite. For the first time in this boring coral casts occur, in which the coral walls have been dissolved away, while the interstices, infilled with calcite, remain. The replaced corals are small examples of *Stylophora* and *Pocillopora*, there are also other fragments which appear to be casts of *Heliopora cærulea*. The remainder of this part of the boring, according to Professor DAVID, is of "sand" or fine rubble.

DETAILS.

(151) [642]. Length 23 millims. A portion of a cylindrical core of hard cream-tinted rock composed of alcyonarian spicules forming part of a stem of *Lobophytum*. They are in the same state of preservation

as those of Core No. 146. Calcite now fills in the interspaces between the spicules. The stem is penetrated by holes made by boring organisms in the same way as in an ordinary coral, and the fine sediment infilling the borings contains *Truncatulina* and *Amphistegina*.

(152–156). Irregular nodular pieces of greyish-white porous rock having a total length of 151 millims. They are apparently composed of fragmental materials, but hardly anything beyond detached alcyonarian spicules can be recognised with a lens.

(157). Length 83 millims., by 79 millims. in width. Cylindrical core of porous greyish-white rock with cavities from which organisms have been dissolved out. The greater part of the core is fragmental, but there are in it casts of small examples of *Stylophora*. Echinid spines.

(158) [643]. Length 100 millims. Greyish-white, porous, and cavernous rock similar to preceding. Principally fragmental, small pieces of *Pocillopora* are, however, present. In a microscopic section the following forminifera can be recognised: *Globigerina* (rare), *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina*, and *Amphistegina*. Echinid spines and plates. The fragments are cemented into a hard rock by finely granular calcite. In some of the cavities laid open by slitting the core, there is fine white powdery material either loose or lightly consolidated.

Depth from Surface, 190–200 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 4 *feet* 8 *inches; Numbers of Cores*, 159–175.

The solid cores of this 10 feet of the boring, taken together, reach to nearly one-half of the distance bored. The cores are for the most part cylindrical, usually cavernous, and also with numerous irregular holes or pores and small slit-like hollows. The rock is a greyish-white moderately hard limestone, readily scratched by a knife. Very little can be distinguished with a lens, beyond that it appears to be fragmental in character and similar to the rock cores from the preceding 40 feet of the boring. Microscopic sections show that it consists principally of foraminifera, many of them broken up into small fragments, and of echinid spines. The only indications of corals are casts of *Stylophora*, *Orbicella*, and small pieces of *Heliopora cærulea* in very imperfect preservation. Possibly some of the now empty cavities may have originally contained corals, but if so, no traces of them remain. The corals form but a very small proportion of this 10 feet of the core. Some of the cavities contain white unconsolidated powder. The rock appears to be mainly a fine organic sediment with foraminifera, now cemented by calcite, in which corals are somewhat rarely present.

DETAILS.

(159) [525, 526]. Length 150 millims. Cylindrical, with cavities, where unconsolidated materials have been removed. Microscopic sections show the following foraminifera: *Discorbina*, *Truncatulina*, *Globigerina*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina*, *Amphistegina*, and *Heterostegina*. Echinid spines plentiful, their structure fairly well shown. The foraminifera less favourably preserved than in higher sections. The finer particles of sediment apparently without structure.

(160). Length 75 millims. General characters similar to preceding. Imperfect cast of *Heliopora cærulea*.

(161–165). Cylindrical cores of the same greyish-white cavernous and porous rock as the preceding, with a total length of 272 millims. Casts of *Heliopora cærulea* are the only organisms recognisable with a lens.

(166) [644]. Length 230 millims. Cylindrical core; rock similar to the preceding. Fragment of cast

of *Heliopora cœrulea*; the walls have disappeared, the larger and smaller tubes are infilled solid with calcareous material. Echinid spines common. A microscopic section shows *Globigerina* (seldom), *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Amphistegina Lessonii* abundant. The section generally like that of Core No. 159.

(167–169). Total length 208 millims. Two cylindrical cores and one nodular piece of the same kind of whitish-grey rock. Numerous thin slit-like hollows about 5 millims. in width by 0·5 millim. in thickness, which may be the casts of detached joints of *Halimeda*. Indications of *Heliopora*. Echinid spines.

(170). Length 150 millims. Core cylindrical, of similar rock to preceding. Some large cavities, one 80 millims. long by 37 millims. wide, now partially filled with cast of *Heliopora cœrulea*. In another hollow, a cast of a small form of *Stylophora* in white, soft, friable material, which goes to powder with a touch. The greater part of the core of fragmental materials.

(171, 172, 173). Total length 138 millims. (No. 173 is not represented). Cores cylindrical, with large cavities now partly filled with casts of *Heliopora cærulea*. The rest of the core fragmental, like the preceding.

(174). Length 40 millims. by 80 millims. in width. A mass of an Astræan coral, perhaps *Orbicella*. The coral structure has been almost entirely removed, and the walls and interspaces are now replaced by calcite. The coral apparently is in position of growth.

(175). Length 125 millims. Cylindrical core of the usual grey hard rock with numerous small irregular hollows. Apparently almost entirely of fragmental materials, the only organisms recognised by the lens are echinid spines and *Amphistegina*.

Depth from Surface, 200–210 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 10 *inches; Numbers of Cores*, 176–178.

The 10 inches of solid cores consist, with the exception of a doubtful nodular fragment, of moderately hard, whitish-grey or cream-tinted cavernous and porous limestone, of the same character as that which has prevailed for the 30 feet above. The rock principally consists of fragmental materials with foraminifera, the cavities are partly filled with casts of corals belonging to *Heliopora* and *Goniastræa*. The fine consolidated sediment in which the foraminifera are embedded is cemented by calcite. There is little to indicate the nature of the organic fragments of which the hollow casts remain. Echinid spines are common. At the depth of 210 feet the cores of 3 inches (75 millims.) diameter end; for the rest of the distance, to the bottom of the boring, the cores are about $2\frac{1}{4}$ inches (56–58 millims.) in diameter.

DETAILS.

(176) [527]. Length 43 millims. An irregular nodule of *Millepora*, much decayed, so that the surface can be scratched with the finger nail. It is extensively bored by *Cliona*. Its condition differs so greatly from that of the proximate cores, that Professor DAVID expresses a doubt whether it may not have accidentally fallen into the bore from the surface.

(177). Length 60 millims. Core cylindrical, of the usual cream-tinted porous rock. Nothing definite can be recognised in it with a lens.

(178) [645]. Length 150 millims. by 77 millims. in diameter. Core cylindrical, with large irregular cavities and numerous pores. Casts of *Heliopora cærulea* in soft powdery material, and *Goniastræa* sp. partially filling the cavities. The greater part of the rock is seen in thin section under the microscope to

be a finely detrital mud cemented by calcite; in this there are entire and fragmentary foraminifera belonging to *Globigerina* (rare), *Polytrema miniaceum*, and *Amphistegina*. *Halimeda*, not in good preservation.

Depth from Surface, 210–220 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 9 *inches; Numbers of Cores*, 179–185.

The solid cores for the most part are nodular lumps, rounded by the drill, of hard cream-coloured porous limestone, similar to the preceding. There are pieces of *Pocillopora*, *Orbicella* and of another astræan coral, either in the condition of casts or with the coral walls partly remaining, but the original fibrous structure is obliterated or replaced by calcite. The interspaces of the corallites are usually infilled with calcite. The larger part of the cores appears to be of fragmentary materials in a fine sediment now cemented by calcite into a fairly hard rock. Foraminifera are plentiful, more particularly *Polytrema planum* and *Amphistegina Lessonii*, echinid spines, *Serpula*, fragments of *Lithothamnion*. A sample of the loose detritus from the boring consists of finely broken-up angular chips of a whitish rock similar to that in the solid pieces of core; under the microscope it is seen to be principally of foraminifera.

DETAILS.

(179). Length 75 millims. Core cylindrical, of porous grey rock. Only echinid spines visible under a lens.

(180) [646]. Length 35 millims. A rounded nodular piece of hard whitish rock, part of it an Astræan coral, the walls and septa remaining in some places, in others removed, leaving only casts. Foraminifera in the detrital material surrounding the coral, include *Globigerina*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina*, *Amphistegina*, very abundant, and *Heterostegina*. Echinid spines, *Serpula*, pieces of crustacean test, and *Lithothamnion*.

(181) [647]. Length 25 millims. A rounded core containing *Orbicella*, in the same state of fossilization as the preceding. *Amphistegina* in sediment filling up a boring in the coral.

(182). Length 30 millims. Fragment of dense whitish rock, mainly composed of casts of *Pocillopora* and *Lithothamnion*.

(183) [648]. Length 33 millims. A nodular lump of porous rock, mainly of foraminifera and fragments of other organisms cemented by calcite. *Orbitolites complanata*, *Cymbalopora*, *Carpenteria*, *Polytrema*, and *Amphistegina*, echinid spines, *Serpula*.

(184). Length 30 millims. by 47 millims. wide. A nodular piece of grey rock; the only traces of organisms are faint casts of *Pocillopora*.

(185) [835, 836]. Sample of loose materials. The fragments are angular or sub-angular; principally of *Carpenteria*, *Polytrema*, and *Amphistegina Lessonii*, also a specimen of *Calcarina hispida*, determined by Mr. CHAPMAN. Fragments of *Lithothamnion*. Some of the organic fragments are partially enclosed by calcite, showing that they have been produced by the breaking up of solid rock.

Depth from Surface, 220–230 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 4 *inches; Number of Core*, 186.

The only solid cores from this 10 feet of the boring are four irregularly worn, nodular pieces of moderately hard whitish-grey limestone, cavernous and porous,

about half of which consists of casts of *Pocillopora* encrusted by *Polytrema planum*, and *Lithothamnion*, and half of fragmental materials, for the most part consolidated and cemented by calcite, but in some of the cavities remaining as an incoherent chalky-looking powder. The foraminifera include *Orbitolites*, *Truncatulina*, *Carpenteria*, *Polytrema miniaceum*, and *Amphistegina Lessonii*. Echinid spines, pieces of *Lithothamnion*, &c. [528, 529, 530, 649].

Depth from Surface, 230–240 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 0; *Numbers of Cores* (*Unconsolidated*), 187, 188.

No solid cores were obtained from this 10 feet, only samples of coarse and fine fragments of limestone broken up by the drill. Professor DAVID states that some of the chips were 1 inch in diameter, but none over 2¼ inches in diameter; these were mixed with "coral sand." The fragments are whitish, angular, such as would be produced by the pounding up of a rock similar to that of the preceding cores. The principal recognisable constituents are foraminifera, often with worn surfaces, also casts of individual corallites of *Pocillopora*, with a few echinid spines and alcyonarian spicules.

DETAILS.

(187) [850]. Mr. CHAPMAN determined *Gypsina globulus*, *Amphistegina Lessonii*, large and very common *Pocillopora* casts, &c.

(188). *Orbitolites marginalis*, *Calcarina hispida*, *Amphistegina*. *Pocillopora* casts.

Depth from Surface, 240–280 *feet; Distance Bored*, 40 *feet; Total Length of Core Obtained*, 1 *inch*; *Numbers of Cores* (*Unconsolidated*), 189–198.

With the exception of an irregular nodule, about an inch in length, of hard, whitish rock, no solid cores were obtained from the boring between 240 and 280 feet; the only specimens to show the character of the rock in this distance of 40 feet are the loose, unconsolidated, fragmentary materials, produced mainly by the grinding action of the drill on the rock passed through. These are mostly angular chips of fairly hard, white limestone of much the same character as those previously described. An examination of the fragments under a lens, as well as of thin sections from them, under a microscope, shows that foraminifera were numerous, and that the rock consisted principally of these organisms in a fine detritus, now cemented together by calcite. The remains of corals in this broken-up material are not numerous, but there are casts of *Pocillopora*, fragments of *Stylophora*, and of some perforate coral. Echinid spines are abundant, also some spicules of alcyonaria. Rarely, stellate ascidian spicules and entomostraca. The single piece of solid core consists of foraminifera and fragmentary materials.

DETAILS.

(189) [837, 838]. From 240 to 245 feet. The broken-up fragments or rock-chips are somewhat coarse, The foraminifera present are *Orbitolites* sp. (fragments), *Carpenteria*, *Tinoporus baculatus*, *Calcarina hispida*, *Polytrema miniaceum*, *Amphistegina Lessonii* (very common), and *Heterostegina depressa*. Echinid spines. Alcyonarian spicules. Casts of *Pocillopora*. Fragments of Cyclostomatous polyzoa. The foraminifera are now loose, but it can be seen that they have been cemented into the rock, and have been set free by the breaking up of the rock by the drill.

(190). From 245 to 250 feet. Fragmental material similar to No. 189. *Cymbalopora tabellæformis*, determined by Mr. CHAPMAN, *Amphistegina*, *Heterostegina*, alcyonarian spicules, and echinid spines, rare.

(191). At 255 feet. Fragmental materials, fine. The greater proportion of the foraminifera present belong to *Amphistegina Lessonii*; there are a few examples of *Orbitolites complanata* and *Marginulina glabra*. Some detached casts of corallites of *Pocillopora*, alcyonarian spicules, and echinid spines.

(192). At 260 feet. Similar to preceding. *Orbitolites*, *Globigerina* (rare), *Amphistegina*, *Heterostegina*. Casts of *Pocillopora*. Fragment of *Halimeda*.

(193–197). From 265 to 275 feet. Five samples of fragmental materials with the same general characters. *Amphistegina Lessonii* is common to all; other and rarer forms are *Orbitolites complanata*, *Textularia siphonifera*, *Carpenteria monticularis*, *Gypsina globulus*, *Calcarina hispida*, and *Heterostegina depressa*. Casts of *Pocillopora*, fragments of perforate coral, perhaps *Porites*. Polyzoa fragments, alcyonarian spicules, and echinid spines.

(197 *bis*) [839]. From 270 to 275 feet. Sample of broken-up angular fragments of rock, somewhat coarse. Thin sections of some of the fragments show, under the microscope, *Carpenteria*, *Polytrema miniaceum*, *P. planum* and *Amphistegina*; the forms are not loose but cemented to the rock fragments. Fragments of *Stylophora* and pieces of perforate coral structure. Echinid spines; consolidated sediment with stellate spicules of *Leptoclinum*.

(198) [650]. From 275 to 280 feet. Length 35 millims. by 52 millims. in width. A nodular piece of whitish, fairly hard, porous rock, consisting of foraminifera and fragmental materials in a matrix of calcite. *Orbitolites*, *Discorbina*, *Truncatulina*, *Polytrema miniaceum*, *P. planum*, *Gypsina*, *Amphistegina*. Alcyonarian spicules.

Depth from Surface, 280–330 *feet*; *Distance Bored*, 50 *feet*; *Total Length of Core Obtained*, 0.

The only materials obtained from the 50 feet of boring between 280 and 330 feet are the broken-up fragments of a fairly hard, whitish limestone obtained from the boring by the sand-pump. The fragments are usually angular, the larger chips are about 3 millims. in length by 2 to 3 millims. in breadth; the smaller only particles of fine dust. The rock consists of foraminifera, principally *Amphistegina Lessonii*; casts of corallites of *Pocillopora*, rarely, fragments of *Millepora*, and of perforate corals; echinid spines and alcyonarian spicules. The broken-up materials indicate that the rock is of the same character as that of the 50 feet above. The samples do not bear any core numbers.

DETAILS.

From 280 to 290 feet. The organisms recognisable in the sample are *Amphistegina*, casts of *Pocillopora*, alcyonarian spicules and echinid spines.

From 290 to 300 feet. The samples of broken-up rock are very similar to the preceding; thin microscopic sections [840] were made from coarse fragments of white rock from 293 feet, which contained *Orbitolites*,

Nonionina (?), *Globigerina*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, and *Heterostegina*. Fragment of *Pocillopora*, showing dark fibrous structure. Echinid spine. *Lithothamnion*.

The samples from 300 to 310 feet are of a fairly hard white rock, with but few organisms to be seen with a lens; *Amphistegina*, alcyonarian spicules, fragments of polyzoa. A sample from 302 feet contained one or two pieces of perforate coral, *Porites* (?).

The fragments from 310 to 320 feet are of hard whitish rock similar to the preceding, with *Amphistegina Lessonii* abundant, and *Orbitolites*. Casts of *Pocillopora*, fragment of *Millepora*, alcyonarian spicules. Echinid spines, polyzoa, *Bairdia* (rare).

From 320 to 330 feet. The samples of powdered materials are still of white rock with the same kinds of organisms. A thin section [841] of some fine material from 325 feet contained *Amphistegina*, *Carpenteria*, *Polytrema miniaceum*, and *Lithothamnion*. *Pocillopora* casts, alcyonarian spicules.

Depth from Surface, 330–373 *feet; Distance Bored*, 43 *feet; Total Length of Core Obtained*, 0.

In this 43 feet of the boring no solid cores were brought up; the only samples of the rocks passed through are the more or less fine, crushed, fragments produced by the action of the drill. This fragmental and powdery material is generally similar to the preceding. It consists of a fairly hard whitish or cream-tinted limestone with numerous foraminifera and pieces of casts of corals, which are distinctly more abundant than in the samples from the preceding 50 feet. Of the corals, *Pocillopora* is most frequently met with; casts of pieces of perforate coral, probably *Porites*, are also common, and a single fragment of a cast of a meandriform coral, (?) *Cœloria* was also noted. The foraminifera usually become detached from the matrix in the crushing of the rock, their surfaces are rough and have lost the polish of recent specimens. The most abundant form is *Amphistegina Lessonii*, other genera represented are *Orbitolites*, *Bolivina*, *Discorbina*, *Globigerina*, *Anomalina*, *Carpenteria*, *Polytrema*, *Tinoporus*, and *Calcarina*. There are also echinid spines, polyzoa, entomostraca, and *Halimeda*.

DETAILS.

From 330 to 340 feet. Somewhat coarse fragmental material, with casts of *Pocillopora* and perforate corals. The foraminifera include *Bolivina*, *Calcarina*, and *Amphistegina*. Fragments of lamellibranchiate shell, polyzoa, echinid spines, *Halimeda* joints.

From 340 to 350 feet. Fine material intermingled with coarser angular fragments about 5 millims. in length. Fragments of *Pocillopora* and pieces of perforate corals. *Porites* (?), numerous. Cast of piece of meandriform coral, *Cœloria* (?). A microscopic section [842] was made from some of the coarser fragments of the white rock brought up from 350 feet; they consisted of pieces of coral showing the fibrous structure, *Nubecularia* (?), *Globigerina*, *Carpenteria*, *Polytrema*, and *Amphistegina*; pieces of fine-grained sediment, with fragments of foraminifera, echinid plates, and joints of *Halimeda*, in a matrix of calcite.

From 350 to 360 feet. Samples of the same kind of rock fragments as the preceding, with fragments of *Pocillopora* and perforate corals; *Amphistegina*, echinid spines, *Halimeda*.

From 360 to 370 feet. Materials for the most part fine, with occasional larger chips of the white rock. In addition to the pieces of *Pocillopora* and perforate corals, there are spicules of alcyonaria, with their tubercles partially decayed and powdery; fragments of polyzoa, *Bairdia*, claws of small crustaceans. *Amphistegina* very common, *Anomalina*, *Discorbina*, and *Calcarina*.

From 370 to 373 feet. Sample of fine powdery material, with angular and partially rounded chips of greyish rock up to 7 millims. across. Fragments of *Pocillopora* common, also pieces of polyzoa. A microscopic section [843] of some of the larger chips of the white rock showed that it consisted of sediment, with entire and fragmentary foraminifera, also pieces of coral showing minute structure. The foraminifera include *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Tinoporus baculatus*, *Calcarina*, and *Amphistegina*.

Depth from Surface, 373–378 *feet; Distance Bored*, 5 *feet; Total Length of Core Obtained*, 1 *foot* 9 *inches; Numbers of Cores*, 199–206.

These are the first solid cores, with the exception of a fragment about an inch in diameter, which have been obtained from the boring in a distance of 143 feet; that is, from a depth of 230 feet to 373 feet, only loose, broken-up small fragments of rock, or so-called sand, reached the surface. The cores from the present 5 feet of the boring are cylindrical, of a hard, compact to minutely porous limestone, whitish-grey, with numerous faint pinkish spots (foraminifera) and occasional hollows where corals have been partially removed. The rock is composed principally of corals and foraminifera with broken branching *Lithothamnion*. There is some amount of fine sediment, very little altered beyond consolidation. The different components are cemented together by a calcite matrix. The corals present belong to *Pocillopora*, undetermined Astræans, *Madrepora contecta*, and *Porites*; they are all in the condition of casts, the original structures having been dissolved away for the most part, or replaced either by calcite, or a fine powdery material. The foraminifera form, perhaps, a larger proportion of the rock than the corals; they principally consist of *Orbitolites* and *Amphistegina Lessonii*. The latter is very abundant, the rock in places being filled with them. Other organisms are echinid spines, stellate ascidian spicules, now replaced by calcite and casts of small gastropods, the shells being entirely removed.

The rock of these cores is harder, more compact, and less porous and granular than that of the cores between 170 and 230 feet, and the foraminifera and *Lithothamnion* in it are in a much better state of preservation.

DETAILS.

(199). From 373 to 378 feet. Length of specimen 25 millims. A nodular piece of hard grey rock, consisting of *Orbitolites* and *Amphistegina*, with fragments of *Lithothamnion* cemented by calcite.

(200). From 373 to 378 feet. Length of specimen 65 millims., breadth 54 millims. Core cylindrical, principally of corals; casts of *Pocillopora*. An Astræan coral poorly shown, and *Madrepora contecta*. Microscopic sections of the corals [531, 532, 532A] show that the fibrous structure is partly retained in *Pocillopora*, though much altered; in the *Madrepora* it has been either removed or replaced by calcite; the original interstices of the coral are in part infilled with fine organic sediment, now consolidated, or with crystalline calcite. The foraminifera present belong to *Orbitolites*, *Globigerina*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina*, *Calcarina*, and *Amphistegina*. Casts of gastropods. *Lithothamnion*.

(201). From 373 to 378 feet. Length of specimen 55 millims. Core rounded, hard, somewhat porous.

Piece of cast of an Astræan coral *Orbicella* (?) and *Madrepora*. Core principally of coral. *Amphistegina Lithothamnion*, and casts of gastropods.

(202). From 373 to 378 feet. Length of specimen 80 millims., breadth 55 millims. Core cylindrical, with imperfect casts of Astræan corals, *Madrepora contecta*, and *Porites*. Larger part of core of *Amphistegina* and *Orbitolites*, with *Lithothamnion*, in a fine sediment, now consolidated into hard rock. Gastropods.

(203). From 373 to 378 feet. Length of specimen 32 millims. Core cylindrical, generally similar to preceding. Casts of *Pocillopora* and *Madrepora*. Foraminifera very numerous, the same as in No. 202.

(204). From 373 to 378 feet. Length of specimen 68 millims. Cylindrical core, with imperfect cast of Astræan coral. Greater part of core consists of fine, calcareous sediment, with minute fragments of foraminifera and other organisms, and great numbers of *Amphistegina Lessonii*, *Orbitolites*, *Polytrema miniaceum*, *Calcarina*, and *Textularia* are also shown in microscopic section [651]. Echinid spines. Casts of ascidian spicules. Nodular fragments of *Lithothamnion*. Organisms well preserved, except corals. Interspaces filled with calcite.

(205) [652]. From 373 to 378 feet. Length 115 millims. Core cylindrical, 55 millims. in diameter, of hard compact to porous rock, generally similar to preceding. Cast of Astræan and of *Madrepora*. Structure of coral dissolved, but the infilled borings of *Cliona* and other organisms remain. Larger part of core consists of foraminifera, which include, besides the predominant *Amphistegina*, *Orbitolites*, *Truncatulina*, *Polytrema miniaceum*, *P. planum*, *Gypsina*, *Calcarina*, *Carpenteria*, and *Heterostegina*. Ascidian spicules replaced by calcite.

(206). From 373 to 378 feet. Length 85 millims. Core cylindrical, rock similar to preceding. Cast of Astræan coral and *Madrepora contecta*, *Orbitolites*, *Amphistegina*, *Lithothamnion*. Casts of gastropods.

Depth from Surface, 378–410 *feet; Distance Bored,* 32 *feet; Total Length of Core Obtained,* 0.

This 32 feet of the boring is only represented by loose fragments, and powder of the rock broken up by the drill. The rock is fairly hard, whitish to somewhat drab-tinted; very little can be seen in it with a lens beyond casts of *Pocillopora* and perforate coral, probably *Porites*, and a few foraminifera, belonging to *Orbitolites*, *Carpenteria*, *Calcarina*, *Amphistegina*, and *Heterostegina*.

Alcyonarian spicules, echinid spines, fragments of polyzoa, and casts of gastropods. Pieces of *Lithothamnion*. A microscopic section shows that the foraminifera, &c., are embedded in sedimentary material, and cemented by calcite.

Details.

From 378 to 390 feet. The samples are of angular or partially rounded chips of rock, up to 12 millims. across. Casts of *Pocillopora* rare, fragments of perforate coral; *Calcarina*, *Amphistegina*, gastropod casts.

From 390 to 400 feet. The samples are of rock chips and powder, partly white, partly of a drab tint. *Pocillopora* casts, fragments of perforate coral numerous, probably *Porites*. Alcyonarian spicules, fragments of polyzoa, *Amphistegina*, echinid spines.

From 400 to 410 feet. Coarse and fine materials intermingled [844]; some of the broken rock chips are 12 millims. across. Fragments of perforate coral *Porites* (?); also numerous pieces of *Pocillopora*. Some of the chips of white rock are seen in thin sections to be composed of fine sedimentary material with *Amphistegina*, *Orbitolites*, *Carpenteria*, and small broken pieces of *Lithothamnion*.

Depth from Surface, 410–420 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 10 *inches; Numbers of Cores*, 207–213.

From the greater part of this 10 feet of the boring only broken up, small fragments and powdered rock were obtained, but between 415 and 417 feet some rounded nodules and partly cylindrical cores of solid rock, having a length altogether of 10 inches, were brought up. These cores are of hard, whitish limestone, partly compact, and partly with pores and small cavities where corals have been dissolved away. The corals are now as casts, poorly preserved; they consist of *Pocillopora*, an Astræan, genus uncertain, *Cœloria*, *Madrepora contecta*, *Madrepora* sp., and portions of the stem of *Lobophytum*. The spicules in this latter partly retain their fibrous structure, but most of them appear in thin section to be changed to an opaque amorphous material. The corals in the solid cores are surrounded by foraminifera and organic fragments, and consolidated by calcite. The foraminifera are of the usual kinds, the genera are given below, their structure is fairly well preserved. *Amphistegina Lessonii* is the predominant form. The crushed rock-fragments appear to be of a similar character to the solid cores.

Details.

(207). From 415 to 417 feet. Length 45 millims. [653]. A nodular core, rounded by drill; it contains casts of an Astræan coral, and of *Madrepora* sp. The rock is mainly foraminiferal; the following genera are present: *Orbitolites*, *Carpenteria*, *Polytrema miniaceum*, *Gypsina*, *Calcarina*, and *Amphistegina*; also alcyonarian spicules and *Lithothamnion* in small fragments.

(208–210). Three irregular rubbly pieces of whitish, hard rock, with a total length of 68 millims. Casts of *Madrepora contecta*, *Orbitolites*, *Amphistegina*. Echinid spines.

(211). Length 55 millims. Cylindrical core, rock cavernous. Casts of *Pocillopora* and *Madrepora*. Foraminifera as in preceding.

(212). Length 50 millims. [654]. Core cylindrical, cavernous. Casts of *Madrepora* and *Pocillopora*. Stem of *Lobophytum*, 40 millims. in length by 8 millims. in diameter, an agglomeration of spicules nearly in contact, the interspaces filled in with calcite. The following foraminifera are shown in a microscopic section of the core: *Orbitolites*, *Textularia*, *Carpenteria*, *Calcarina*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*, also fragments of *Lithothamnion*.

(213). Length 40 millims. Irregular lump of white cavernous rock, worn by the drill; it contains casts of *Cœloria* and *Madrepora*.

From 417 to 420 feet. Sample of broken-up angular fragments of rock and powdered material brought up in the sand-pump. Casts of *Pocillopora*, and fragments of perforate corals. Alcyonarian spicules, echinid spines. Microscopic sections of some of the rock chips [845] exhibit casts of corals and foraminifera in a fine detrital sediment. *Orbitolites*, *Spiroloculina*, *Carpenteria*, *Polytrema miniaceum*, *Gypsina inhærens*, and *Amphistegina*.

Depth from Surface, 420–450 *feet; Distance Bored*, 30 *feet; Total Length of Core Obtained*, 1 *foot* 6 *inches; Numbers of Cores*, 214–222.

Between 420 and 430 feet of the boring no solid cores were brought up, nor has any of the broken-up and powdered rock been preserved; below 430 feet, solid cores

... of the boring, with a total length of 1 foot 6 inches; ... the broken-up rock-chips and dust were brought to ... principally cylindrical with some irregular lumps ... of whitish and whitish-grey, hard, calcareous rock, ... present and partly dissolved, and generally compact ... miniferal and detrital. The rock interspaces are filled ... casts: they belong to *Seriatopora* and *Madrepora*. ... some of the cores appear to consist entirely of them, ... character as the preceding: in one instance, however, ... the rock was filled with *Calcarina hispida*, with a ... *Polytrema*. *Lithothamnion* is present, encrusting ... of *Halimeda*; also echinid spines and casts of ... powdered rock from 448 feet are generally fine, they ... perforate corals, with *Amphistegina*.

Details.

... millims. An irregular lump of hard whitish rock, porous and ... with *Amphistegina* and empty casts of gastropods.

... in diameter. Cylindrical core of whitish grey rock, porous, ... cemented by calcite. No corals recognised. A microscopic ... form is *Calcarina hispida*, with some *Orbitolites*, and *Polytrema* ... in small fragments.

... core of hard whitish-grey rock, minutely porous, consisting of ... also cast of a piece of *Seriatopora*.

... rock cavernous with branching *Seriatopora* and *Madrepora*, ... and *Orbitolites*.

... with a total length of 50 millims. Whitish-grey rock, like ... *Lithothamnion*. The parasitic borings in the corals now ... networks in the cavities from which the coral structures have ...

... rock similar to the preceding with casts of *Seriatopora* and ...

... up fragmental and powdered material, mostly of small ... and perforate corals and rarely *Calcarina*, and ...

... Distance Bored, 7 feet: Total Length of Core ... Numbers of Cores, 223–229.

... the boring, between 450 and 453 feet, there ... length of 1 foot 5 inches; the remaining 4 feet ... chips and powdered rock, broken up by the ... moderately hard, porous, and in part, cavernous

limestone, containing numerous casts of *Madrepora*, *Pocillopora*, and *Seriatopora*, with encrusting *Polytrema planum* and *Lithothamnion*. There is much fine organic sediment with foraminifera, cemented by calcite. Echinid spines. *Halimeda*, casts of gastropods.

DETAILS.

(223). From 450 to 453 feet. Length 31 millims. An irregular lump, worn by drill, of white, porous and cavernous, calcareous rock, with casts of *Pocillopora*, *Carpenteria*, *Amphistegina*, and Cheilostomatous polyzoa.

(224, 225). Two pieces of cylindrical core with a total length of 87 millims. Rock porous and cavernous where corals have been dissolved out. Casts of *Millepora* (?), *Seriatopora*, and *Madrepora*. Infilled *Cliona* boring.

(226). Length 75 millims. Cylindrical core of whitish, porous and cavernous rock with casts of *Seriatopora* and branching *Madrepora*. A microscopic section [656] shows that the corals are inclosed in fine sediment with fragments of *Polytrema*, *Globigerina*, casts of gastropods and echinid spines, and cemented together by calcite.

(227, 228). Two cylindrical cores with a total length of 145 millims. Rock hard, white, and cavernous, like preceding. Numerous casts of *Pocillopora* and *Madrepora*, encrusted by *Lithothamnion*. Casts of gastropods. *Cliona* borings.

(229). Length 75 millims. Cylindrical core of hard whitish rock [533, 534], with cast of *Madrepora* and a considerable amount of encrusting *Polytrema planum* and *Lithothamnion*. The larger part of the rock consists of fine calcareous sediment with *Orbitolites*, *Textularia*, *Carpenteria*, echinid spines, *Halimeda*, and numerous other fragments of indeterminable organisms, cemented by calcite into a hard rock.

Sample of loose fragments of white rock, broken up by the drill. A microscopic section [846] of some of the rock chips, the largest of which was 1·7 millims. across, showed the following foraminifera, determined by Mr. CHAPMAN; *Nonionina* (?) *Carpenteria*, *Polytrema miniaceum*, *Calcarina*, and *Amphistegina*.

From 453 to 457 feet. Sample of angular chips of whitish rock, broken up by the drill. Very littl distinguishable under a lens beyond an occasional specimen of *Amphistegina*.

Depth from Surface, 457–468 *feet; Distance Bored*, 11 *feet; Total Length of Core Obtained*, 7 *inches; Numbers of Cores*, 230–233.

From this 11 feet of the boring only four pieces of solid core were secured. These fragments are of a whitish and greyish-white, porous limestone, in which under a lens very little structure can be seen; thin microscopic sections show that it is composed of very fine sediment containing minute detrital, mostly unrecognisable, fragments of foraminifera. There are some obscure indications of corals, but too indefinite for determination.

DETAILS.

(230). From 457 to 468 feet. Diameter 40 millims. A lump of whitish fairly compact rock, rounded by drill. A microscopic section [657] shows that it is a consolidated calcareous mud with fragments of *Carpenteria*, *Amphistegina*, and *Heterostegina*. Only a single entire specimen of *Amphistegina* present in the slide.

(231). Length 35 millims. A rounded piece of white rock apparently similar to the preceding.

(232). Diameter about 50 millims. A fragment of white porous rock, rounded by drill. The only objects distinguishable under a lens are obscure casts of corals and gastropoda.

(233). Length 45 millims., diameter 55 millims. Cylindrical core of the same white porous rock as the

preceding. It is a very fine grained sediment of the same character as Core 230. Mr. CHAPMAN recognises, in a microscopic section [658], fragments of *Textularia*, *Pulvinulina*, *Orbitolites*, *Carpenteria*, and *Polytrema miniaceum*.

Depth from Surface, 468–480 *feet*; *Distance Bored*, 12 *feet*; *Total Length of Core Obtained*, 6 *inches*; *Numbers of Cores*, 234–236.

Only three pieces of solid core with a total length of 6 inches were obtained from this 12 feet of the boring. The rock is whitish, moderately hard limestone, with numerous slit-like hollows, the empty casts of some organism, possibly *Halimeda*-joints, and with occasional small cavities where corals may have been dissolved out. One piece of the core is compact to minutely porous, and consists of very fine sediment with detrital fragments. The loose materials broken up by the drill, consist of angular and blunted chips of white rock with a few detached *Amphistegina*, alcyonarian spicules (rare) and echinid plates.

DETAILS.

(234). Length 50 millims. Core cylindrical, with some cavities probably due to corals, since *Cliona* borings are present in them. Rock mainly fragmental in appearance, only *Orbitolites* to be seen under lens.

(235). Length 45 millims. Cylindrical core of the same character of rock as preceding.

(236). Length 44 millims. Core rounded by drill, of whitish rock. A microscopic section [659] shows that it is fine calcareous sediment with minute detrital fragments of organisms. The only recognisable bodies are casts of small echinid spines and small pieces of *Lithothamnion*.

Depth from Surface, 480–487 *feet*; *Distance Bored*, 7 *feet*; *Total Length of Core Obtained*, 0.

Only loose small chips, subangular and partially rounded, of white and cream-tinted rock, were obtained from this 7 feet of the boring. The broken grains range from 0·5 millim. to 4 millims. in diameter. No organisms are seen under a lens beyond a chance alcyonarian spicule.

Depth from Surface, 487–497 *feet*; *Distance Bored*, 10 *feet*; *Total Length of Core Obtained*, 1 *foot* 1 *inch*; *Numbers of Cores*, 237–241.

The solid cylindrical cores are of a whitish or cream-tinted calcareous rock, fairly hard, cavernous in places, compact to porous. It contains casts of *Madrepora* in poor preservation. There is a considerable amount of *Lithothamnion*. The greater part of the cores consist of a very fine consolidated calcareous sediment with foraminifera; echinid spines are also common and some *Halimeda*-joints. Gastropod casts. The materials are cemented by calcite.

DETAILS.

(237). Length 37 millims. Lump of whitish, hard, porous rock, rounded by drill; apparently of fine sedimentary material. The only organisms recognisable under a lens are casts of *Madrepora*.

(238). Length 20 millims. A fragment of cavernous white rock, showing casts of *Madrepora* and *Amphistegina*.

(239). Length 80 millims. Cylindrical core of whitish, porous rock, some casts of corals, and a large amount of *Lithothamnion*. Sedimentary material with *Amphistegina* and echinid spines.

(240). Length 100 millims. by 55 milims. in diameter. Cylindrical core of whitish-grey, cavernous and porous rock, with casts of perforate corals, ? *Madrepora*. A microscopic section [660] shows that the rock is largely of a very fine calcareous sediment with casts of gastropods, echinid spines, foraminifera, pieces of *Lithothamnion*, and *Halimeda*. The following genera were determined by Mr. CHAPMAN: *Miliolina*, *Orbitolites*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, and *Gypsina*.

(241). Length 80 millims. Cylindrical core, rock similar to preceding. Cast of *Madrepora*. A considerable amount of *Lithothamnion*; echinid spines.

Depth from Surface, 497–505 *feet*; *Distance Bored*, 8 *feet*; *Total Length of Core Obtained*, 10 *inches*; *Numbers of Cores*, 242–252.

With the exception of one cylindrical piece, the solid cores are irregular fragments of limestone, partly rounded by drill. The rock is whitish and whitish-grey, hard and cavernous, where corals have been dissolved away. The corals are very imperfect casts of *Madrepora*. The greater part of the rock is a very fine calcareous sediment, filled with minute organic fragments, with foraminifera, echinid spines, *Lithothamnion* and casts of gastropods. A sample of loose, broken-up fragments of white rock brought up by the sand-pump, corresponds in character to the rock of the solid cores, the only organisms recognisable in it with a lens are *Amphistegina*, *Heterostegina*, and fragments of *Pocillopora*.

DETAILS.

(242). Length 22 millims. An irregular fragment of hard whitish-grey rock, with poorly shown casts of perforate coral.

(243). Length 48 millims. A piece of similar rock to preceding, cavernous where *Madrepora* had been partially dissolved out and in part porous. A microscopic section [661] shows that the rock is mainly composed of fine calcareous sediment with minute organic particles and specimens of *Miliolina*, *Orbitolites*, *Carpenteria*, and *Polytrema miniaceum*. Spines and plates of echinids, also numerous small detached pieces of *Lithothamnion*.

(244). Core not in place.

(245–251). Irregular pieces of white rock, with a total length of 120 millims.; there are, in some pieces, casts of branching *Madrepora*, but the greater part of the rock is of consolidated calcareous sediment, similar to the preceding core, No. 243, the only organisms visible under a lens are echinid spines and fragments of *Lithothamnion*.

(252). Length 80 millims. Cylindrical core of greyish-white rock, with casts of branching *Madrepora* extending vertically through it, the hollow casts enclosed by consolidated detrital sediment, with echinid spines, *Lithothamnion*, &c.

Depth from Surface, 505–517 *feet*; *Distance Bored*, 12 *feet*; *Total Length of Core Obtained*, 7 *inches*; *Numbers of Cores*, 253–258.

Only a length of 7 inches of solid core was brought to the surface from the 12 feet of boring; the remaining 11 feet 5 inches being scantily represented by small rock chips

preceding. It is a very fine grained sediment of the same character as Core 230. Mr. CHAPMAN recognises, in a microscopic section [658], fragments of *Textularia*, *Pulvinulina*, *Orbitolites*, *Carpenteria*, and *Polytrema miniaceum*.

Depth from Surface, 468–480 *feet; Distance Bored*, 12 *feet; Total Length of Core Obtained*, 6 *inches; Numbers of Cores*, 234–236.

Only three pieces of solid core with a total length of 6 inches were obtained from this 12 feet of the boring. The rock is whitish, moderately hard limestone, with numerous slit-like hollows, the empty casts of some organism, possibly *Halimeda*-joints, and with occasional small cavities where corals may have been dissolved out. One piece of the core is compact to minutely porous, and consists of very fine sediment with detrital fragments. The loose materials broken up by the drill, consist of angular and blunted chips of white rock with a few detached *Amphistegina*, alcyonarian spicules (rare) and echinid plates.

DETAILS.

(234). Length 50 millims. Core cylindrical, with some cavities probably due to corals, since *Cliona* borings are present in them. Rock mainly fragmental in appearance, only *Orbitolites* to be seen under lens.

(235). Length 45 millims. Cylindrical core of the same character of rock as preceding.

(236). Length 44 millims. Core rounded by drill, of whitish rock. A microscopic section [659] shows that it is fine calcareous sediment with minute detrital fragments of organisms. The only recognisable bodies are casts of small echinid spines and small pieces of *Lithothamnion*.

Depth from Surface, 480–487 *feet; Distance Bored*, 7 *feet; Total Length of Core Obtained*, 0.

Only loose small chips, subangular and partially rounded, of white and cream-tinted rock, were obtained from this 7 feet of the boring. The broken grains range from 0·5 millim. to 4 millims. in diameter. No organisms are seen under a lens beyond a chance alcyonarian spicule.

Depth from Surface, 487–497 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 1 *foot* 1 *inch; Numbers of Cores*, 237–241.

The solid cylindrical cores are of a whitish or cream-tinted calcareous rock, fairly hard, cavernous in places, compact to porous. It contains casts of *Madrepora* in poor preservation. There is a considerable amount of *Lithothamnion*. The greater part of the cores consist of a very fine consolidated calcareous sediment with foraminifera; echinid spines are also common and some *Halimeda*-joints. Gastropod casts. The materials are cemented by calcite.

DETAILS.

(237). Length 37 millims. Lump of whitish, hard, porous rock, rounded by drill; apparently of fine sedimentary material. The only organisms recognisable under a lens are casts of *Madrepora*.

(238). Length 20 millims. A fragment of cavernous white rock, showing casts of *Madrepora* and *Amphistegina*.

(239). Length 80 millims. Cylindrical core of whitish, porous rock, some casts of corals, and a large amount of *Lithothamnion*. Sedimentary material with *Amphistegina* and echinid spines.

(240). Length 100 millims. by 55 milims. in diameter. Cylindrical core of whitish-grey, cavernous and porous rock, with casts of perforate corals, ? *Madrepora*. A microscopic section [660] shows that the rock is largely of a very fine calcareous sediment with casts of gastropods, echinid spines, foraminifera, pieces of *Lithothamnion*, and *Halimeda*. The following genera were determined by Mr. CHAPMAN : *Miliolina*, *Orbitolites*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, and *Gypsina*.

(241). Length 80 millims. Cylindrical core, rock similar to preceding. Cast of *Madrepora*. A considerable amount of *Lithothamnion* ; echinid spines.

Depth from Surface, 497–505 *feet*; *Distance Bored*, 8 *feet*; *Total Length of Core Obtained*, 10 *inches*; *Numbers of Cores*, 242–252.

With the exception of one cylindrical piece, the solid cores are irregular fragments of limestone, partly rounded by drill. The rock is whitish and whitish-grey, hard and cavernous, where corals have been dissolved away. The corals are very imperfect casts of *Madrepora*. The greater part of the rock is a very fine calcareous sediment, filled with minute organic fragments, with foraminifera, echinid spines, *Lithothamnion* and casts of gastropods. A sample of loose, broken-up fragments of white rock brought up by the sand-pump, corresponds in character to the rock of the solid cores, the only organisms recognisable in it with a lens are *Amphistegina*, *Heterostegina*, and fragments of *Pocillopora*.

DETAILS.

(242). Length 22 millims. An irregular fragment of hard whitish-grey rock, with poorly shown casts of perforate coral.

(243). Length 48 millims. A piece of similar rock to preceding, cavernous where *Madrepora* had been partially dissolved out and in part porous. A microscopic section [661] shows that the rock is mainly composed of fine calcareous sediment with minute organic particles and specimens of *Miliolina*, *Orbitolites*, *Carpenteria*, and *Polytrema miniaceum*. Spines and plates of echinids, also numerous small detached pieces of *Lithothamnion*.

(244). Core not in place.

(245–251). Irregular pieces of white rock, with a total length of 120 millims. ; there are, in some pieces, casts of branching *Madrepora*, but the greater part of the rock is of consolidated calcareous sediment, similar to the preceding core, No. 243, the only organisms visible under a lens are echinid spines and fragments of *Lithothamnion*.

(252). Length 80 millims. Cylindrical core of greyish-white rock, with casts of branching *Madrepora* extending vertically through it, the hollow casts enclosed by consolidated detrital sediment, with echinid spines, *Lithothamnion*, &c.

Depth from Surface, 505–517 *feet*; *Distance Bored*, 12 *feet*; *Total Length of Core Obtained*, 7 *inches*; *Numbers of Cores*, 253–258.

Only a length of 7 inches of solid core was brought to the surface from the 12 feet of boring; the remaining 11 feet 5 inches being scantily represented by small rock chips

and dust pounded up by the drill. The cores are partly cylindrical, partly irregular pieces of a greyish-white, moderately hard, cavernous and porous limestone, in which very little can be distinguished with a lens. Casts of *Madrepora* are only occasionally present. The rock, as seen in microscopic sections, principally consists of foraminifera, entire and fragmentary, in a fine detrital material with polyzoa; casts of lamellibranchs, alcyonarian spicules, echinid spines, and *Serpula* tubes. The organisms and mud are cemented by calcite, the pores in the rock are lined by scalenohedral crystals. The powdered materials are angular, and blunted chips of the same greyish-white rock as the solid cores, the only forms recognised amongst them with a lens are some *Amphistegina* with roughened surfaces, and small fragmentary casts of *Pocillopora*.

DETAILS.

(253, 254). Two irregular fragments of hard, greyish-white limestone, 38 millims. long, with alcyonarian spicules, *Amphistegina*, and *Lithothamnion*.

(255). Length 67 millims. Cylindrical core, with hollows where corals have been removed. A microscopic section [662] shows that it is principally of consolidated fragmental materials and partly a fine sediment. In it there are numerous broken pieces of *Polytrema planum*, together with *Orbitolites*, *Miliolina*, *Carpenteria*, *Polytrema miniaceum*, *Gypsina vesicularis*, var. *discus*, *Amphistegina*, and *Heterostegina*. A single delicate branch of *Madrepora*, cast only. Polyzoa.

(256, 257). Length 31 millims. Two irregular fragments of core similar to preceding.

(258). Length 42 millims., diameter 55 millims. Cylindrical core of whitish-grey limestone, cavities partly occupied by casts of *Madrepora*. A microscopic section [663] shows that it is foraminiferal and fragmental. It contains the same foraminifera as core 255, with the addition of *Textularia*. Structure of foraminifera fairly well preserved. Alcyonarian spicules, echinid spines, *Serpula*, and *Lithothamnion*.

Depth from Surface, 517–526 *feet; Distance Bored*, 9 *feet; Total Length of Core Obtained*, 1 *foot* 4 *inches; Numbers of Cores*, 259–267.

The solid cores are in part cylindrical, in part irregular fragments of whitish and greyish-white limestone, frequently cavernous. The cavities are produced by the dissolution of corals; they are in part occupied by the casts in sediment of the interstices of the corals, and by the solid infillings of the borings of *Cliona* and other organisms which remain as an intricate mesh-work of nodose calcareous threads after the structure of the coral has been dissolved away. The corals in these cores are more numerous than in those immediately preceding, they consist of *Pocillopora* and *Madrepora*, with a small quantity of *Montipora*. There is, further, a considerable amount of encrusting *Lithothamnion*. The intermediate material is mainly fragmental, with foraminifera. Alcyonarian spicules, echinid spines, lamellibranch shells, and casts of gastropods.

DETAILS.

(259, 260). Total length 60 millims. Two irregular pieces of whitish cavernous rock, with casts of *Pocillopora*, *Madrepora*, and *Montipora*. *Orbitolites*, *Amphistegina*; small nodular lumps and branches of *Lithothamnion*.

(261). Length 58 millims. Core cylindrical, very cavernous and porous, casts of *Pocillopora* and *Madrepora conferta*. Infilled *Cliona* borings, very numerous in the coral cavities. *Carpenteria*, *Lithothamnion*.

(262). Length 35 millims. Core cylindrical, whitish rock similar to preceding, with casts of *Pocillopora* and *Madrepora*.

(263). Length 20 millims. A rounded piece of greyish-white, porous limestone. Some casts of undeterminable corals; the larger part of the rock is seen under the microscope [664] to consist of organic fragments, with *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina vesicularis*, var. *discus*, *Amphistegina*, *Heterostegina*, alcyonarian spicules, echinid spines, and lamellibranchiate shells. *Lithothamnion* and *Halimeda* are rare.

(264). Length 50 millims. Cylindrical core of white, very porous limestone; casts of corals, *Amphistegina*, and *Lithothamnion*.

(265). Length 45 millims. Irregular piece of white rock; cast of *Madrepora*. Rock mainly fragmental, with *Amphistegina*.

(266). Length 66 millims. Cylindrical core, hard, compact where *Lithothamnion* occurs. Casts of *Pocillopora* and *Madrepora*. Infilled *Cliona* borings.

(267) [535]. Length 60 millims. Cylindrical core of greyish-white, hard, compact limestone, with some cavities where *Pocillopora*, *Seriatopora*, and gastropod shells have been removed. Encrusting *Lithothamnion* very abundant. Consolidated fragmental materials, with *Truncatulina*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina vesicularis*, var. *discus*, *Calcarina*, and *Amphistegina*. Alcyonarian spicules. *Cliona* borings. Cemented by calcite.

Sample of loose fragments, broken up by drill. Coarse and fine angular and blunted chips of white rock with fragments of coral casts, including *Pocillopora*. *Amphistegina*. Alcyonarian spicules, polyzoa, rare.

Depth from Surface, 526–546 *feet; Distance Bored*, 20 *feet; Total Length of Core Obtained*, 4 *feet; Numbers of Cores*, 268–289.

The solid cores, for the most part cylindrical, are of white and greyish-white, hard limestone, generally cavernous, due to the removal of corals; in places porous, and not infrequently compact where *Lithothamnion* occurs. The corals belong to *Pocillopora*, which is very abundant, occasional Astræan corals, very imperfectly shown, *Prionastræa* (?), *Cœloria*. A fungid coral, *Halomitra* (?) and *Madrepora*, which is not so frequent in these cores as in the preceding. Alcyonarian spicules. *Lithothamnion* is abundant and forms an important constituent of the rock. There is a considerable amount of fragmental materials with foraminifera. *Polytrema planum* occurs as encrusting layers alternating with *Lithothamnion*. The coral structures and the gastropod shells in some of these cores are now replaced by crystalline calcite.

DETAILS.

(268). Length 23 millims. An irregular fragment of white limestone with casts of *Madrepora*.

(269). Length 75 millims., diameter 55 millims. Core cylindrical, of white, hard, mostly compact rock [665] with some casts of *Pocillopora* and *Madrepora*. A piece of a compound Astræan, showing casts of three or four calices. The greater part of the core consists of consolidated fine calcareous sediment with organic fragments and foraminifera, including *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina vesicularis*, var. *discus*, common, and *Amphistegina*. Alcyonarian spicules, and echinid spines. *Lithothamnion* in white, nodular fragments and also encrusting.

(270). Length 30 millims. A lump of hard, greyish-white, compact rock, rounded by drill, with fragments of *Cœloria* and of another Astræan coral and *Lithothamnion*.

(271). Length 80 millims. Core cylindrical, of hard, mostly compact limestone, like preceding, with casts of *Pocillopora* and *Madrepora*. Greater part of core of encrusting *Lithothamnion* and consolidated fragmental materials, cemented by calcite. *Amphistegina*.

(272). Length 75 millims. Cylindrical core, like the preceding. Casts of *Madrepora*, the branches in a vertical position, and *Pocillopora*. In some of the corals the wall structure is now replaced by crystalline calcite, whilst the parasitic borings are infilled by consolidated mud. Larger part of core of detrital material with *Amphistegina* and *Lithothamnion*, also *Serpula*. Turbinate gastropod, 30 millims. in height and 36 millims. in basal width, the walls replaced by crystalline calcite, the exterior encrusted by *Lithothamnion*, and the interior filled with hardened sediment.

(273). Length 60 millims. Cylindrical core of hard, whitish rock, porous in places, *Pocillopora* casts, *Halomitra* (?), the wall structure replaced by calcite. The greater part of the core of hardened detrital materials with *Amphistegina* and *Lithothamnion*.

(274). Length 43 millims. Cylindrical; rock similar to preceding. *Pocillopora* in part as hollow casts, in part with the walls replaced by calcite, piece of Astræan coral, *Prionastræa* (?) Core mainly of hardened detrital materials [666], principally broken fragments of foraminifera and *Lithothamnion*, in fine sediment cemented by calcite. *Carpenteria*, *Polytrema planum*, *Gypsina*, *Amphistegina*.

(275). Length 100 millims., diameter 55 millims. Cylindrical, cavernous where branching *Pocillopora* and *Madrepora* have been dissolved. The larger part of the core of detrital materials, like the preceding.

(276). Length 78 millims. Cylindrical; whitish hard rock, cavernous where *Pocillopora* and gastropods have been removed.

(277–280). Four pieces of cylindrical cores, total length 181 millims., of whitish, hard, in part cavernous limestone, with casts of *Pocillopora*. The cores consist largely of detrital materials with foraminifera and *Lithothamnion*.

(281–283). Three irregular cores with a total length of 142 millims., of hard, white limestone, cavernous, with casts of *Pocillopora*, *Madrepora*, and turbinate gastropods. Detrital materials as in preceding.

(284). Length 75 millims. Cylindrical; hard, greyish-white limestone, cavernous, casts of *Cœloria*. A microscopic section [667] shows that the rock mainly consists of thick encrusting layers of *Lithothamnion*, alternating with *Polytrema planum*. Fragmental materials in fine sediment with alcyonarian spicules, *Carpenteria*, *Polytrema miniaceum*, *Gypsina*, and *Amphistegina*.

(285–289). Five pieces of cylindrical and irregular cores, with a total length of 227 millims. Whitish, hard limestone, similar to preceding; cavernous, where corals have been removed, compact and dense where *Lithothamnion* occurs. *Pocillopora*, common; *Cœloria* and another Astræan coral, rare. *Lithothamnion*, abundant. The details of the fragmental part of the rock are only distinguishable in microscopic sections.

Samples of loose materials brought up by sand-pump; they consist of angular and blunted small fragments of white hard rock. Only a few specimens of *Amphistegina* with rough surfaces, and chance fragments of coral, are recognisable under a lens.

Depth from Surface, 546–555 *feet; Distance Bored*, 9 *feet; Total Length of Core Obtained*, 10 *inches; Numbers of Cores*, 290–296.

The cores, mostly cylindrical, are of whitish and whitish-grey hard limestone with cavernous hollows in places. Other portions are of compact, dense rock which consists largely of *Lithothamnion*. The corals, for the most part, have disappeared, only an Astræan and casts of some perforate coral have been recognised. Fragmental materials and fine sediment with foraminifera form a large part of the cores. The

organisms are cemented by calcite into hard rock. Of the foraminifera, *Carpenteria* is abundant, and *Polytrema planum*. Alcyonarian spicules, echinid spines. Very little can be seen of the character of the rock except in the microscopic sections.

DETAILS.

(290, 291). Two fragments of hard white limestone, with a total length of 40 millims. Only layers of *Lithothamnion* can be seen with lens.

(292). Length 45 millims. Cylindrical core, of whitish limestone, with cavities from which corals may have been removed. Rock principally of encrusting layers of *Lithothamnion*, with consolidated fragmental materials.

(293). Length 75 millims. Core cylindrical, of whitish-grey hard limestone, cavernous, like the preceding. *Astræa* (?) and perforate coral. Larger part of core of undulating layers of *Lithothamnion* and fragmental material.

(294). Length 50 millims. Core cylindrical, of whitish hard rock, with cavities and small hollows. Microscopic sections [536, 668] show that the rock mainly consists of branching *Lithothamnion*, encrusted in places by *Polytrema planum*. Fragmental materials, mostly of foraminiferal *débris*, fill up the interspaces; consolidated with these in the fine sediment are the following foraminifera:—*Cymbalopora*, *Orbitolites*, *Carpenteria*, *Planorbulina*, *Polytrema miniaceum*, *Gypsina discus*, and *Calcarina*. Alcyonarian spicules, echinid spines.

(295). Length 25 millims. Core cylindrical; rock similar to preceding, cast of large gastropod.

(296). Length 130 millims. Core cylindrical; hard greyish-white rock, with large vertical hollow cavities. A microscopic section [669] shows the rock to be filled with *Carpenteria* and *Polytrema miniaceum*, together with layers of *Lithothamnion*. *Orbitolites*, *Planorbulina*, *Gypsina discus*, and *Amphistegina* are also present in the fine calcareous sediment, which is cemented by calcite. Some of the hollows are lined with scalenohedral crystals.

Depth from Surface, 555–567 *feet; Distance Bored*, 12 *feet; Total Length of Core Obtained*, 0.

No solid cores were obtained from the 12 feet of the boring; the only materials brought to the surface being the pounded angular and rounded fragments of rock raised by the sand-pump. These are of hard, whitish rock, with many small pieces of crystalline calcite, probably due to the infilling of the casts of corals, &c. Very little can be seen in the incoherent materials under a lens, but thin sections [847] show the following foraminifera embedded in a fine consolidated sediment, also with obscure indications of casts of corals:—*Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Gypsina inhærens*, *Amphistegina*, and *Heterostegina depressa*. The largest chip in the slide is 2 millims. by 1·3 millims.

Depth from Surface, 567–578 *feet; Distance Bored*, 11 *feet; Total Length of Core Obtained*, 2 *inches; Numbers of Cores*, 296*a*, 296*b*.

With the exception of two small irregular pieces of solid core, the materials from this 11 feet of the boring consist only of loose fractured particles of cream-tinted rock of the same general character as the preceding. The particles are, however,

larger, ranging to 6 millims. in diameter, and there are amongst them casts of *Pocillopora* and perforate corals, somewhat large foraminifera, and casts of small gastropods. The pieces of solid cores contain casts of a small *Astræa*, *Madrepora*, and numerous foraminifera in a fine consolidated and now somewhat altered sediment. Amongst the foraminifera, *Cycloclypeus* was recognised for the first time in the boring. The rock is cemented by calcite.

DETAILS.

(296*a*) [670]. Length 22 millims. An irregular piece of greyish-white, cavernous and porous rock, with casts of a small *Astræa* and *Madrepora*. Foraminifera numerous, belonging to *Textularia*, *Truncatulina*, *Globigerina*, *Planorbulina*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, large and numerous, *Heterostegina* and *Cycloclypeus*. *Halimeda* joints, indistinct echinid spines.

(296*b*) [671]. Length 30 millims. A fragment of cream-tinted rock, porous, with indistinct casts of corals and numerous foraminifera. *Carpenteria*, *Polytrema*, *Amphistegina*, *Heterostegina* and *Cycloclypeus*. Echinid spines.

Coarse fragments of broken-up greyish-white rock, with casts of *Pocillopora*, *Astræa*, perforate corals, and *Orbitolites*, *Amphistegina* and *Heterostegina*.

Depth from Surface, 578–598 *feet; Distance Bored*, 20 *feet; Total Length of Core Obtained*, 10 *inches; Numbers of Cores*, 297–304.

The solid cores consist of several irregular fragments and three cylindrical cores of a greyish-white, moderately hard and very porous limestone, in which there are a few obscure casts of corals, apparently of *Madrepora*, and a compound fungid coral. The greater portion of the cores seems to consist of foraminifera, with alcyonarian spicules and casts of small gastropods. The incoherent materials, brought to the surface by the sand-pump, are fine and moderately coarse chips of a rock similar to that of the solid cores; the only organisms seen with a lens are foraminifera, broken echinid spines, and very rarely a small piece of a cast of coral. Professor DAVID considers that these represent cuttings through fine coral rubble.

DETAILS.

(297–301). Five irregular pieces of white porous rock, length altogether 126 millims. Cast of fungid coral. The rock appears to be mainly of sedimentary material with *Cycloclypeus*, *Amphistegina* and *Heterostegina*.

(302). Length 36 millims. Core, cylindrical, of whitish-grey limestone, with numerous pores and small hollows. Only organisms to be seen with a lens are *Amphistegina* and casts of small gastropods.

(303). Length 23 millims. Cylindrical cores, similar to preceding. Cast of Astræan coral. Alcyonarian spicules. *Amphistegina*.

(304). Length 74 millims. Core, cylindrical; of whitish-grey, porous rock, similar to the two preceding specimens. Cast of *Madrepora*, apparently in position of growth, also of another coral supposed by Professor DAVID to be *Heliopora cærulea*, but I cannot recognise it with certainty.

Microscopic sections [537, 538] show that the limestone is mainly of fine fragmental materials with numerous foraminifera belonging to *Miliolina*, *Discorbina*, *Globigerina*, *Bolivina*, *Carpenteria*, *Polytrema planum*, *Calcarina*, *Amphistegina*, very abundant, *Heterostegina* and *Cycloclypeus*. Alcyonarian spicules. Polyzoa.

The rock contains occasional casts of *Madrepora* and *Stylophora*, but the larger proportion is of consolidated organic calcareous sediment with entire and fragmentary foraminifera, echinid spines, casts of gastropods and of *Halimeda*, cemented by calcite. The loose materials brought up by the pump, consist of small angular chips of limestone, similar to that in the solid cores.

DETAILS.

(307, 308). Total length 100 millims. One piece of cylindrical core and one irregular fragment. The rock, hard, greyish-white, very cavernous as well as porous. In one of the larger hollows, casts of *Madrepora* and the infilled borings of *Cliona*. A microscopic section [675] shows that it consists mainly of fine detrital sediment with numerous entire and fragmentary forms of *Miliolina*, *Globigerina*, rare, *Carpenteria*, *Pulvinulina*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Echinid spines.

(309). Length 50 millims. A piece of the usual porous white limestone, rounded by drill. In thin sections [539, 540] it is seen to consist of fine-grained sediment cemented by calcite, with *Spiroloculina*, *Globigerina*, *Carpenteria*, *Truncatulina*, *Polytrema*, *Gypsina*, and *Amphistegina* (?) Echinid spines.

(310). Length 18 millims. An irregular fragment of rock similar to preceding.

(311). Length 63 millims. Core cylindrical, of the usual whitish-grey limestone with numerous hollows. The only objects visible under a lens are echinid spines and casts of gastropods.

(312). Length 45 millims. by 56 millims. in diameter. Core cylindrical, of hard whitish limestone, like the preceding. Cast of *Stylophora*. Echinid spines, and gastropod casts. The larger part of the core apparently consists of fine sedimentary materials cemented by calcite.

Depth from Surface, 637–643 *feet; Distance Bored*, 6 *feet*; *Total Length of Core Obtained*, 2 *feet* 1 *inch*; *Numbers of Cores*, 313–320.

The solid cores from this portion of the boring are, for the most part, cylindrical, with some irregular fragments rounded by the drill. The first piece of the core (No. 318) from approximately the level of 637 feet is a whitish, moderately hard, cavernous and porous limestone, of similar characters to the solid cores in the preceding 60 feet of the boring. The remaining cores, Nos. 314–320, from between 638–643 feet, differ from those immediately above in being harder, less cavernous, and generally more compact. The rock is greyish-white, not infrequently speckled; the whitish spots representing the foraminifera and other organisms, and the greyish portions the crystalline infilling. This is markedly different from that in the core above, where the partially free crystals lining the pores are scalenohedral, whereas in these lower cores they are for the most part rhombohedral, and are now dolomitic. Accompanying this change, the organisms in the rock are better shown, and can be readily distinguished with a lens. Coral casts are only occasionally present, they form but a small proportion of the cores, and they are in very poor preservation. *Pocillopora*, *Hydnophora* (?), and *Madrepora* are the only genera recognised. As usual, their structures have been dissolved, and they have been subsequently replaced by crystalline dolomite, while the interstices and the parasitic borings of *Cliona*, &c., have been infilled with fine organic sediment. The larger part of these cores consist of foraminifera of the same kinds as in the cores above; the encrusting *Polytrema*

Depth from Surface, 643–652 *feet; Distance Bored*, 9 *feet: Total Length of Core Obtained*, 3 *feet* 5 *inches; Numbers of Cores*, 321–335.

The cores from this 9 feet of the boring are mostly cylindrical, of a hard, whitish-grey, sometimes with a mottled appearance, porous, and occasionally cavernous dolomitic limestone. The rock is very crystalline, the pores are lined with rhombohedral crystals, and the foraminifera and other objects are encrusted with the same sparkling crystals. These cores exhibit the same general characters as the preceding from No. 314 (638 feet) downwards, but they contain more corals, and a less proportion of foraminifera and fragmental materials. The corals are in very poor preservation, only represented by imperfect casts, not infrequently showing only the infilled borings of *Cliona* and other organisms; as a rule, the casts are now infilled with crystalline dolomite, whilst the original interstices and the *Cliona* borings are filled with fine organic detritus. The corals include *Pocillopora*, *Stylophora*, small Astræans, *Madrepora*, *Porites*, and *Astræopora*; also a single example of *Millepora*. They are usually surrounded by a thick white layer of *Polytrema planum*, with some *Lithothamnion*. The spaces between the corals are filled with the usual kinds of foraminifera, echinid spines, and *Halimeda*. The foraminiferal structure is altered, and partially obliterated in this rock.

Details.

(321, 322). Total length 160 millims. Two cylindrical cores of mottled, greyish-white, dolomitic rock, hard, porous, with some cavities. Several casts of corals, now replaced so that identification is impossible; there are traces of *Pocillopora* and of perforate corals. But little shown of the fragmental part of the core beyond *Heterostegina* and echinid spines.

(323). Length 43 millims. An irregular piece of white rock, with casts of the surface of a branching *Pocillopora* and a *Madrepora*.

(324). Length 88 millims. Core cylindrical, of hard, greyish-white, porous dolomite. Several casts of perforate corals (*Porites?*), mostly filled up by crystalline materials. *Polytrema planum*, forming small nodules. *Heterostegina*; echinid spines.

(325). Length 74 millims. Core cylindrical. Several corals present as casts. *Millepora*, *Stylophora*, *Madrepora* and others not determinable. The corals surrounded by layers of *Lithothamnion* and *Polytrema planum*. Foraminiferal structure obscured and partly obliterated [547, 548]. *Truncatulina*, *Carpenteria*, *Polytrema miniaceum*, *Gypsina*, *Amphistegina*, *Heterostegina*. Echinid spines abundant. Section of crustacean carapace. *Halimeda*-joints.

(326). Length 63 millims. Cylindrical core, whitish-grey, porous, and with some cavities. Casts of *Madrepora* and *Porites* encrusted by layers of *Lithothamnion* and *Polytrema*. *Cliona* borings. Large spines of echinids. Foraminifera not recognisable with a lens.

(327). Length 77 millims. Cylindrical. Larger part of cores of casts of *Madrepora* and *Porites*, overgrown by *Lithothamnion* and *Polytrema*.

(328). Length 98 millims. Cylindrical. Greyish-white, mottled, hard, porous dolomitic rock, with a few cavities. Many solidly infilled casts of *Madrepora*, *Porites*, and other corals not determinable. Encrusted similarly to the preceding. Coral interstices filled with fine detrital mud. The areas between the corals likewise filled in with fine fragmental materials [678, 679], containing *Miliolina*, *Pulvinulina*, *Carpenteria*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Echinid spines numerous,

the structure nearly obliterated. *Halimeda.* The pores in the rock are lined mainly with rhombohedral crystals of dolomite, but some calcite scalenohedra are present as well.

(329, 331). Total length 202 millims., diameter 56 millims. Three cylindrical pieces of core of whitish-grey, mottled, dolomitic limestone, porous, and with occasional cavities. Largely of casts of *Madrepora*, *Porites*, and, perhaps, some other corals as well. Corals in part hollow, but with infilled *Cliona* borings, or solidly replaced with crystalline materials, and with the usual encrusting layers of *Polytrema planum* and *Lithothamnion*, alternating with each other. The foraminifera include [549, 550] *Globigerina*, *Amphistegina*, and *Heterostegina*; their minute structure is much altered, and scarcely recognisable. Echinid spines abundant. *Halimeda*, imperfectly preserved.

(332) [551]. Length 42 millims. A fragment, rounded by drill, of white, hard, porous, dolomitic limestone with casts of a simple Astræan, and of a perforate coral, which are encrusted, as usual, by *Polytrema* and *Lithothamnion*. The foraminifera recognisable are *Globigerina*, *Amphistegina*, and *Heterostegina*. Echinid spines.

(333). Length 37 millims. Cylindrical. Rock similar to preceding, with several small casts of *Stylopora*, *Madrepora* (?) and *Astræopora*, encrusted by *Polytrema planum*. Altered fragmental material [552], with *Gypsina*, *Amphistegina* and *Heterostegina*. Alcyonarian spicule, echinid spines, *Halimeda* rare.

(334). Length 48 millims. Cylindrical. Greyish-white, hard, very porous, dolomitic rock, with several casts of *Pocillopora*, *Seriatopora*, an Astræan, and *Porites*, all unfavourably preserved. Encrusted by *Polytrema*, and occasionally by thin layers of *Lithothamnion*. The foraminifera include [553] *Spiroloculina*, *Miliolina*, *Globigerina*, *Gypsina*, *Amphistegina*, and *Heterostegina*. Echinid spines, *Halimeda* abundant. Pores lined by rhombohedral crystals, and the rock generally very crystalline. The structure of the various organisms, as a rule, much altered.

(335). Length 88 millims. Cylindrical. Rock similar to preceding. About two-thirds of the core consists of casts of corals, *Pocillopora* and *Madrepora*, encrusted by the usual organisms [554, 555]. *Miliolina*, *Amphistegina*, *Heterostegina*. *Halimeda*. Casts of gastropods.

Depth from Surface, 652–660 feet; Distance Bored, 8 feet; Total Length of Core Obtained, 1 foot 9 inches; Numbers of Cores, 336–343.

The cores are cylindrical, they consist of a whitish to whitish-grey, moderately hard to soft, very porous, dolomitic limestone. The first core, No. 336, is very similar to those immediately preceding it; the remainder of this series contain a variable amount of the usual coral casts, which, like those in the cores above, are also enclosed by thick layers of *Polytrema planum* and *Lithothamnion*; but the larger part of the cores is composed of foraminifera and *Halimeda*-joints, packed together closely; the interspaces between are, however, only partially occupied by crystalline materials, so that the rock is very porous and light, and, in some cases, sufficiently soft to be scratched by the finger nail. The corals, so far as can be judged from the poorly preserved casts, comprise *Orbicella*, *Fungia*, *Madrepora*, *Porites*, *Turbinaria*, and *Cyphastræa*. The foraminifera belong to the usual forms; we notice the reappearance of *Orbitolites* and of *Cycloclypeus*, which is very abundant in the Core No. 343, about 660 feet. The rhombohedral crystals of dolomite are present in this rock, the same as in the preceding. *Halimeda* is generally distributed. Echinid spines. Casts of gastropods and lamellibranchs.

Details.

(336). Length 46 millims. Cylindrical. Whitish, moderately hard, porous dolomite rock. Casts of *Madrepora*, and *Turbinaria*, overgrown by *Polytrema planum*. The rest of core foraminiferal [556] with *Miliolina*, *Orbitolites*, rare, *Amphistegina*, and *Heterostegina*. Echinid spines, casts of gastropods, and *Halimeda*. The corals are as usual destroyed, but a clue to their characters may be obtained occasionally from the casts of their interspaces which have been filled by fine consolidated sediment. The white bands of encrusting *Polytrema* form a prominent feature in this rock.

(337). Length 105 millims. Cylindrical core, scratched readily by knife, of cavernous and very porous rock; largely of coral casts thickly encrusted with layers of *Polytrema planum*. The corals are *Cyphastræa* resembling *C. Savignyi*, E. and H., and *Porites*. The areas between the corals are filled almost wholly with foraminifera, which are only partially cemented by crystalline dolomite, so that there are numerous pores. They include [557] *Orbitolites*, *Truncatulina* (?), *Polytrema miniaceum*, *Gypsina*, *Amphistegina*, and *Heterostegina*. The structure of the foraminifera only partially preserved.

(338). Length 86 millims. Cylindrical core. Greyish-white, light, very porous rock, similar to the preceding, but with a lesser proportion of corals. *Fungia* (one specimen), *Madrepora*, *Porites*, and *Turbinaria* are present. Some of the corals are now preserved as a labyrinthic mesh-work lined by rhombohedral crystals: they are as usual overgrown by *Polytrema planum*. The foraminifera [558, 559] include the same forms as in the preceding core No. 337. Test plates of echinids, *Halimeda*, and *Lithothamnion*.

(339). Length 66 millims. Cylindrical, of dolomite [680], very similar to the preceding. Several coral casts, one a specimen of *Orbicella*, encrusted by layers of *Polytrema planum*, 12 millims. in thickness. *Carpenteria*, *Gypsina*, *Amphistegina*, *Heterostegina*.

(340). Length 53 millims. Cylindrical, of the same whitish-grey porous rock as the preceding, with nodular masses of *Pocillopora* and *Porites* (?) encrusted by *Polytrema planum*. Larger part of core [560] consists of a packed mass of foraminifera including *Orbitolites*, *Discorbina*, *Gypsina*, *Amphistegina*, and *Heterostegina*, very abundant. Cast of lamellibranch. Echinid spines, Cheilostomatous polyzoa and *Halimeda*.

(341). Length 82 millims. Cylindrical. Rock dolomitic, soft, can be scratched by finger nail, very porous, like the preceding. Mainly foraminiferal [561, 562, 563] *Orbitolites*, *Textularia*, *Carpenteria*, *Polytrema planum*, *Gypsina*, *Amphistegina*, *Heterostegina*, and *Cycloclypeus*. *Halimeda*-joints.

(342) Length 38 millims. Cylindrical; whitish rock, porous, soft, can be scratched in places by finger nail. Cast of *Madrepora*. Greater part of core foraminiferal [564A] with *Globigerina*, *Amphistegina*, *Heterostegina*, and *Cycloclypeus*, numerous. *Halimeda*-joints common. Large echinid spines.

(343). Length 47 millims. Cylindrical core, soft, scratched by finger nail, light and minutely porous, friable, so that it can be rubbed down into a finely crystalline white powder. Mainly of foraminifera [564]. Large specimens of *Cycloclypeus*; *Polytrema planum*, and other forms like those in the preceding core. *Halimeda*. The organisms are very unfavourably preserved.

Depth from Surface, 660–670 *feet*; *Distance Bored*, 10 *feet*; *Total Length of Core Obtained*, 8 *inches*; *Numbers of Cores*, 344–347.

There are only four short cylindrical cores, altogether about 8 inches in length, from this 10 feet of the boring. With one exception the cores are of a whitish, chalky-looking, soft and porous dolomitic rock similar to those immediately preceding. Corals are rare, *Pocillopora*, one cast of *Fungia* and another of *Madrepora* were noted. The cores are nearly entirely of foraminifera, in poor preservation, *Cycloclypeus* being the predominant form. One piece of core, No. 345, is of a hard greyish-white dolomite, and differs so much in its hardness and general appearance from the soft

cores above and below, that Professor DAVID questions if it is in its proper position. A microscopic section, however, shows that it contains the same kinds of foraminifera as the cores above and below, so that probably it belongs here.

DETAILS.

(344). Length 35 millims. Cylindrical, whitish, can be scratched by finger nail, light and very porous. Fragment of cast of *Fungia* shown at one end of the core. Mainly foraminiferal [565], *Cycloclypeus*, *Carpenteria*, abundant, with *Globigerina*, *Polytrema planum*, *Amphistegina* and *Heterostegina*. Echinid spines.

(345). Length 55 millims. Cylindrical. Greyish-white, hard, somewhat porous. Casts of *Pocillopora* and *Madrepora*. *Alveolina* (?), nodular lumps of *Polytrema planum* with large cells; *Cycloclypeus*; *Carpenteria*, common; *Amphistegina Lessonii*; *Heterostegina depressa*; *Halimeda* common; *Lithothamnion*. This core contains a fair proportion of casts of corals, and the foraminifera are not numerous; further it is hard and in part compact [565a]. In spite of the differences between it and the cores above and below, the occurrence of the same foraminifera, which have been determined by Mr. CHAPMAN, leads to the belief that it has not been misplaced, and in this case we have a hard layer of the rock intercalated between soft beds.

(346). Length 68 millims. Cylindrical core, of whitish, porous, soft dolomite, similar to Cores 342–344. Mainly of foraminifera, partially cemented with minute rhombohedral crystals. In a microscopic section [566] the following genera are shown:—*Orbitolites*, *Textularia*, *Truncatulina*, *Globigerina*, *Polytrema planum*, *Amphistegina*, *Heterostegina* and *Cycloclypeus*. Echinid spines.

(347). Length 38 millims. Cylindrical. The same white porous rock, apparently containing the same foraminifera as the preceding. A fragment of a cast of perforate coral.

Depth from Surface, 670–691 *feet*; *Distance Bored*, 21 *feet*; *Total Length of Core Obtained*, 1 *foot* 11 *inches*; *Numbers of Cores*, 348–356.

From the 21 feet of this boring, the length of the cores obtained only amounts to 23 inches. The cores are cylindrical, very uniform in character, consisting of a milk-white chalky-looking, light and very porous dolomitic rock, which can be scratched by the finger nail, and is friable enough to be rubbed to powder between the fingers. It is similar to the preceding 12 feet, from Core No. 341. The rock is mainly foraminiferal, but occasional layers of *Montipora* and casts of *Stylophora* and an Astræan are present. The *Montipora* appears to be in position of growth. Amongst the foraminifera *Cycloclypeus* is present in all the cores, but not in any great numbers. *Polytrema planum* with the large cells continues. Polyzoa. Some *Lithothamnion* and *Halimeda* present, but not common. All the organisms are in very unfavourable preservation; they are lightly cemented by minute rhombohedra of dolomite, many of which have darkened centres.

DETAILS.

(348). Length 93 millims. Core cylindrical, of the usual white, porous rock. Casts of *Montipora* in undulating horizontal layers, probably in position of growth. The coral structure removed away, the interstices occupied by the dolomitic crystalline matrix. Core mainly foraminiferal [567]; *Globigerina*, *Polytrema planum*, with large chambers, *Amphistegina*, *Heterostegina* and *Cycloclypeus*. *Halimeda*, *Lithothamnion* (?).

(349) [568]. Length 70 millims. Light, porous, friable dolomite, similar to preceding. Cast of Astræan coral. Largely of foraminifera; the same forms as in the preceding core, No. 348. *Cycloclypeus*, but not abundant. Echinid spines, polyzoa, *Halimeda*.

(350). Length 63 millims. Cylindrical core, soft, porous, like preceding, but the organisms yet more unfavourably preserved. Rhombohedral crystals with opaque (white) centres. Almost entirely of foraminifera [569]. *Globigerina*, *Carpenteria* (?), *Polytrema planum*, rare, *Amphistegina*, *Heterostegina* and *Cycloclypeus*. *Lithothamnion* (?).

(351). Length 70 millims. Rock similar to the core above. A few casts of a small *Montipora* (?). The same foraminifera [570] as in No. 350, with the addition of *Truncatulina*. Echinid spines.

(352). Length 72 millims. Cylindrical, soft, friable, like the preceding. Several casts of perforate coral, probably *Porites*. Rock principally foraminiferal. *Discorbina* (?), *Globigerina*, *Polytrema planum*, *Amphistegina*, and *Cycloclypeus*. The forms are greatly altered, and scarcely recognisable in thin sections [571]. Plates and spines of echinids. *Lithothamnion* (?). *Halimeda*.

(353). Length 28 millims. Cylindrical. Rock similar to 352. Scarcely anything to be seen with a lens beyond a *Cycloclypeus*.

(354). Length 70 millims. Core cylindrical, of the same soft, porous, chalky-looking dolomite as the preceding. Cast of piece of *Stylophora*; some casts either of branching or simple Astræan coral. Largely of foraminifera [572]; the most prominent are nodular lumps of *Polytrema planum*, with the large chambers; it grows round the corals and other organisms. *Globigerina*, *Carpenteria*, *Gypsina*, *Amphistegina*, *Heterostegina*, and *Cycloclypeus*, fairly common. *Lithothamnion* in small branches, and encrusting layers. Echinid plates and spines. *Serpula*-tubes.

(355). Length 82 millims. Core cylindrical. The same soft, porous, dolomitic rock, readily scratched by finger nail. Almost entirely foraminiferal, the same forms as in Core 354, with the exception of *Carpenteria* and *Gypsina*. No corals recognised. The organisms are, for the most part, very obscurely shown; in a microscopic section [573] rhombohedra of dolomite, with opaque centres, are very numerous. Echinid spines. *Halimeda* and *Lithothamnion*.

(356). Length 23 millims. Core cylindrical, of the same description of rock as preceding. The only objects to be distinguished with a lens are casts of perforate coral, *Polytrema planum*, and *Cycloclypeus*.

Depth from Surface, 691–698 *feet*; *Distance Bored*, 7 *feet*; *Total Length of Core Obtained*, 2 *feet* 2 *inches*; *Numbers of Cores*, 357–366.

The character of the cylindrical cores from this part of the boring is closely similar to that of the rock above, from 658 feet (Core 341) downwards. The rock is milk-white, porous, soft, readily scratched with the finger nail, and friable. It appears to be formed of minute rhombohedral crystals of dolomite. Occasional casts of a small *Astræa*, and of a small fungid coral, are present, but the rock principally consists of foraminifera, very poorly preserved. *Polytrema planum* and *Cycloclypeus* are the most prominent forms. Echinid spines and plates. Both *Halimeda* and *Lithothamnion* occur.

DETAILS.

(357). Length 45 millims. Cylindrical. The foraminifera [574] recognised belong to *Globigerina*, *Polytrema planum*, with large chambers, *Amphistegina*, *Heterostegina*, and *Cycloclypeus*. Echinid spines. *Halimeda* common.

(358). Length 69 millims. Cylindrical. Rock resembling the preceding, Core 357, and with the same organisms [575]. Nodular lumps and encrusting layers of the *Polytrema planum* compose a large amount

of the core. *Halimeda* and *Lithothamnion* (?). Structure of the organisms replaced by the crystalline dolomite.

(359). Length 69 millims. Cylindrical. The same soft, white, porous rock as the preceding. The only coral recognised is a cast of *Pocillopora*. Principally of foraminifera [576], including *Pulvinulina*, *Globigerina*, *Carpenteria*, *Polytrema planum* (large chambered variety) prominent, *Gypsina*, *Amphistegina*, *Heterostegina* and *Cycloclypeus*. *Halimeda* abundant.

(360). Length 93 millims. by 54 millims. in diameter. Core cylindrical, of the same kind of rock as the foregoing. A single cast of an Astræan coral, apparently a simple form. Probably the same foraminifera as in the preceding, but only *Carpenteria*, *Polytrema*, *Amphistegina*, and *Cycloclypeus* are visible under a lens.

(361). Length 85 millims. Cylindrical; the same kind of rock as previously. Cast of undetermined coral. The same forms of foraminifera [577] as in core 359, with the addition of *Textularia*: *Polytrema planum* very prominent. *Halimeda*-joints numerous; *Lithothamnion*, not common, encrusting the *Polytrema*. Echinid spines and plates.

(362). Length 76 millims. Cylindrical, rock similar to preceding. Cast of small fungid coral. Mostly foraminiferal, probably same forms as preceding, but only *Polytrema planum* and *Cycloclypeus* can be recognised under a lens. *Halimeda* abundant.

(363). Length 62 millims. Cylindrical. Rock white, porous, readily scratched by nail, like preceding. Cast of small *Fungia* [578]. *Globigerina*, *Polytrema planum*, *Amphistegina*, *Heterostegina*, and *Cycloclypeus*. *Halimeda*-joints, abundant and fairly well preserved.

(364). Length 35 millims. Cylindrical. White porous dolomitic rock like the preceding. Casts of one or two small corals, but not determinable. The foraminifera [579] include *Orbitolites*, *Globigerina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema planum*, very prominent, forming encrustations with subordinate alternating layers of *Lithothamnion*: *Amphistegina*, *Heterostegina*, and *Cycloclypeus*, common. *Halimeda* abundant.

(365, 366). Total length 124 millims. Two cylindrical pieces of core of the same dolomitic rock as the preceding. They are largely foraminiferal [580, 581, 582] and contain the same forms as the preceding, with the exception that *Discorbina* occurs, whilst *Carpenteria* is absent. No corals have been noticed. *Polytrema planum* is abundant and forms nodular lumps consisting of undulating layers, alternating with layers of *Lithothamnion*. *Cycloclypeus* common. *Halimeda*-joints.

The core No. 366 is the last in the series of the upper part of the Main boring from the surface down to 698 feet. With the lower part of the boring, which extended from 698 feet to the bottom at 1114 feet from the surface, a new series of numbers for the cores was introduced beginning with 1A and reaching to 709A.

Depth from Surface, 698-706 *feet; Distance Bored*, 8 *feet; Total Length of Core Obtained*, 8 *inches; Numbers of Cores*, 1A, 2A.

The cores are cylindrical, of whitish, porous, dolomitic limestone, harder than the preceding, so that they cannot be scratched by the finger nail. The rock is mainly composed of foraminifera and *Halimeda*-joints. Only a single small cast of *Madrepora* recognised.

DETAILS.

(1A). Total length 109 millims. Two cylindrical pieces of whitish dolomitic rock, very porous and crystalline. *Amphistegina*, *Heterostegina*, and *Cycloclypeus*. *Halimeda*, abundant. Echinid plates.

(2A). Length 83 millims., diameter 56 millims. Dolomite, similar to preceding, the pores lined by minute rhombohedral crystals. The most abundant constituent is *Halimeda*, a small cast of *Madrepora* is also present. The foraminifera include [681] *Polytrema planum*, *Gypsina globulus*, *Amphistegina*, *Heterostegina*, and *Cycloclypeus*. Echinid spines in fragments. Cast of lamellibranch.

Depth from Surface, 706–716 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 1 *foot; Numbers of Cores*, 3A–8A.

Cores cylindrical, with one exception, of whitish, soft, minutely porous, crystalline dolomitic limestone. Not soft enough to be scratched by finger nail, but yields readily to a knife. Like the preceding the cores mainly consist of foraminifera and *Halimeda* in a fine amorphous sediment, now cemented by crystals of dolomite. Only a single specimen of *Madrepora* noted. *Amphistegina*, *Polytrema* and *Cycloclypeus* are the most prominent foraminifera. The organisms are very poorly preserved.

DETAILS.

(3A). Length 30 millims. A fragment of core rounded by drill. *Amphistegina* is the only form distinguishable with a lens.

(4A) [682]. Length 98 millims. Whitish, fine-grained, minutely porous, dolomite. A microscopic section shows that the greater part of the core consists of dark, amorphous sediment, cemented by small rhombohedral crystals of dolomite. A single piece of *Madrepora* and of another perforate coral, encrusted by *Polytrema planum; Amphistegina*, and *Heterostegina. Serpula. Halimeda* joints.

(5A, 6A). Total length 52 millims. Two cylindrical cores of similar rock to the preceding. No corals noted. Same foraminifera as before, with the addition of *Cycloclypeus. Halimeda.*

(7A). Length 50 millims. The same white, porous rock as the preceding. Mainly of foraminifera: *Amphistegina, Heterostegina, Polytrema*, and *Cycloclypeus*. A few joints of *Halimeda*.

(8A) [683]. Length 66 millims. Whitish, fine-grained, minutely porous dolomite, with the same foraminifera as the preceding, embedded in a fine amorphous sediment. Echinid spines. *Halimeda.*

Depth from Surface, 716–736 *feet; Distance Bored*, 20 *feet; Total Length of Core Obtained*, 2 *feet* 4 *inches; Numbers of Cores*, 9A–16A.

Cores cylindrical, of whitish, soft, porous, finely crystalline dolomitic limestone, similar to preceding. The rock is sometimes sufficiently soft to be marked by the finger nail. It essentially consists of foraminifera and *Halimeda*; corals are rare; one piece of an Astræan, one of *Madrepora*, and several casts of a small fungid, probably *Cycloseris*, are all that have been noted. Of the foraminifera, *Polytrema planum* is largely developed, forming prominent nodular lumps, some reaching to 38 millims. in diameter, encrusting *Halimeda* and other organisms. *Amphistegina* numerous. *Cycloclypeus* still occurs. *Alveolina* noted definitely for the first time in No. 13A, about 725 feet. In the cores from the lower part the foraminifera and other organisms are better preserved, and the fine amorphous material no longer prevails.

DETAILS.

(9A). Length 43 millims. Whitish, soft, scratched by nail. *Heterostegina, Cycloclypeus.* Cast of *Cycloseris.*

(10A). Length 86 millims., diameter 56 millims. Whitish, soft, like preceding, light, and very porous. A piece of an Astræan coral cast, and the cast of a small *Cycloseris* (?). The core mainly

foraminiferal; *Polytrema planum, Gypsina globulus, Amphistegina, Heterostegina, Cycloclypeus*, common. *Lithothamnion*.

(11A) [684]. Length 190 millims. White, porous, soft, with occasional small cavities. Casts of a few small corals, very indistinct, *Cycloseris* (?) and *Madrepora* (?). The larger part of the core foraminiferal; including *Carpenteria, Globigerina, Gypsina, Polytrema planum* growing, in nodose masses, round corals, gastropods, and other bodies, *Amphistegina Lessonii*, very numerous, *Heterostegina*, and *Cycloclypeus* also very abundant. Casts of gastropods.

(12A). Length 72 millims. White, very porous, soft; can be scratched by the finger nail. No corals recognised. Nodules of *Polytrema planum* very prominent, forming a considerable part of the core. Other foraminifera the same as in the preceding. *Halimeda, Lithothamnion*.

(13A). Length 74 millims. White, porous, soft, like preceding. Cast of *Cycloseris*. Mainly foraminiferal, but joints of *Halimeda* very numerous. *Alveolina* definitely noticed for the first time. *Amphistegina, Heterostegina, Polytrema planum, Cycloclypeus*.

(14A, 15A) [685]. Total length 176 millims. White, very porous dolomitic rock, somewhat harder than the preceding cores. The pores and small cavities and also the foraminifera lined by rhombohedral crystals. The foraminifera are indistinctly shown; they consist of *Alveolina, Globigerina, Gypsina globulus, Calcarina hispida, Amphistegina, Heterostegina, Polytrema planum*, and *Cycloclypeus*. *Halimeda* very abundant. Echinid spines.

(16A) [686]. Length 60 millims. White, very porous, dolomitic limestone. *Halimeda*-joints form a considerable part of the rock. Foraminifera numerous; of the same forms as in the preceding core, but the incrusting *Polytrema* does not seem to be present. The only coral is a small cast of *Cycloseris*, cf. *C. cyclolites*.

Depth from Surface, 736–748 *feet; Distance Bored*, 12 *feet; Total Length of Core Obtained*, 3 *feet* 5 *inches; Numbers of Cores*, 17A–31A.

Cores cylindrical, of whitish to cream-tinted, for the most part porous, dolomitic limestone. The first four cores, Nos. 17A to 20A, are of soft rock, which can be scratched by the nail, the succeeding cores are much harder, but these are readily scratched by knife. The cores vary much in their degree of porosity, the upper and some of the lower are open in texture and resemble the preceding cores, whilst in others the interspaces have been almost entirely infilled with the crystalline dolomite, and the rock is nearly compact. There is not not much difference in the organisms composing the cores; the rock is mainly foraminiferal in character. The most prominent forms are *Polytrema planum*, and large varieties of *Amphistegina Lessonii* and *Heterostegina depressa*. *Alveolina* and *Cycloclypeus* are present in the upper cores, but have not been noticed in the lower. Corals are comparatively scarce and only occur as indistinct casts. One or two Astræans, *Cyphastræa, Cycloseris, Madrepora*, and *Porites*. *Halimeda* is no longer abundant as in the preceding cores, *Lithothamnion* is present as thin crusts alternating with *Polytrema planum*.

DETAILS.

(17A). Length 36 millims. Whitish, soft, porous, can be scratched by finger nail. Mainly of foraminifera and joints of *Halimeda*. *Amphistegina, Heterostegina, Cycloclypeus*. *Cycloseris* cast and piece of perforate coral.

(18A, 19A, 20A). Total length 140 millims. Cores, cylindrical, soft like preceding. The same foraminifera as in the previous core. No corals noticed. *Halimeda*.

(21A) [687]. Length 82 millims. Whitish, porous, hard, with some small cavities mainly of foraminifera; *Alveolina*, *Polytrema planum*, forming nodules, some of which are 48 millims. in diameter; *Gypsina globulus*, *Amphistegina*, and *Heterostegina*, both large and numerous; *Nonionina*. Only one piece of perforate coral noticed, probably *Madrepora*. *Halimeda*; thin crusts of *Lithothamnion*. The organisms lined by rhombohedral crystals of dolomite.

(22A) [688]. Length 97 millims. Rock of same character as preceding. Mainly foraminiferal; *Orbitolites*, *Alveolina*, *Globigerina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Cast of *Cycloseris* and of small perforate coral. *Halimeda*, *Lithothamnion*. Casts of gastropods.

(23A, 24A). Total length 166 millims. Cylindrical cores of whitish, hard, very porous rock, similar to the preceding. Almost entirely of foraminifera, the only coral observed is a cast of a small Astræan. The most prominent foraminifera are the nodular lumps of *Polytrema planum*; between these *Amphistegina* and *Heterostegina* are packed, but there are no signs of any arrangement in bedding layers. The interspaces are lined, but not infilled, with the dolomitic crystals. *Halimeda* and *Lithothamnion*.

(25A) [689]. Length 103 millims. Whitish, hard, nearly compact, dolomitic limestone. The foraminifera in this core are very closely packed together, and the interspaces are largely filled up with crystals of dolomite. They comprise *Orbitolites*, *Bdelloidina*, *Globigerina*, *Gypsina*, *Polytrema planum*, *Amphistegina*, and *Heterostegina*. Cast of *Cycloseris*. Plates of echinids. *Halimeda*.

(26A, 27A). Total length 164 millims. Whitish, hard, partly porous, partly compact, principally of foraminifera similar to the preceding. Cast of *Cycloseris* (?) and of a perforate coral. Casts of lamellibranchs.

(28A) [690]. Length 56 millims. Rock similar to the preceding. Cast of *Cyphastræa* and of a perforate coral. Mainly foraminiferal. *Discorbina* (?), *Carpenteria*, *Polytrema planum*, *Amphistegina*, and *Heterostegina*, very numerous.

(29A, 30A). Total length 95 millims. Whitish to cream-coloured dolomitic limestone, in part porous. Almost wholly of foraminifera, of the same kinds as in the preceding cores. Casts of *Cycloseris*.

(31A). Length 98 millims. Whitish to grey, hard, very porous in some places, in others nearly compact. Casts of *Cycloseris* and of *Porites*. Mainly foraminiferal; *Polytrema planum*, forming large irregular nodules, *Amphistegina* and *Heterostegina*, numerous. Alcyonarian spicules. *Lithothamnion*.

Depth from Surface, 748–763 feet; Distance Bored, 15 feet; Total Length of Core Obtained, 7 feet 1 inch; Numbers of Cores, 32A–54A.

The solid cores from this part of the boring are nearly half the length of the distance passed through, and, from this to the bottom of the boring the proportion of the solid cores is about 85 per cent. of the boring, or, in other words, each 10 feet of the boring is represented by 8½ feet of solid cylindrical rock-cores. The cores between 748 and 763 feet are of whitish-grey, hard, porous to compact, and occasionally cavernous, dolomitic limestone. The degree of porosity depends on the extent to which the interspaces between the organisms have been filled up with the crystalline dolomite which cements them together. In some of the cores, moreover, there is fine amorphous sediment, now consolidated, in the spaces between the foraminifera, &c. The cores of the upper portion, Nos. 32A–36A, between 748 and 752 feet, consist principally of foraminifera, with occasional casts of corals; below 752 feet to 763 feet the same foraminifera are present, but they are associated

with a considerably larger quantity of corals, which give a distinctive feature to the cores. The corals are casts only; they are very imperfectly preserved; in some the structures are dissolved away, leaving vacant spaces; in others the corals are replaced with crystalline dolomite, which likewise fills up the calices, &c. In many instances the corals appear to be in the position of growth. They include *Pocillopora*, *Hydnophora*, *Orbicella*, and other undetermined Astræan genera, *Cycloseris*, *Turbinaria*, and *Porites*. Of the foraminifera the most prominent is *Polytrema planum*, which encrusts small corals and other organisms, forming nodules up to 50 millims. in diameter. Other genera present are *Orbitolites*, *Haddonia*, *Textularia*, *Globigerina* (rare), *Carpenteria*, *Gypsina*, *Amphistegina* numerous, *Heterostegina*, and *Cycloclypeus*. Alcyonarian spicules, *Serpula*, casts of *Cliona* borings, *Halimeda*, and *Lithothamnion*.

DETAILS.

(32A). Length 94 millims. Greyish, hard, very porous dolomite. Prominent nodular lumps of *Polytrema planum*, *Amphistegina*, *Heterostegina*, very large and numerous, mainly composing the core. Small perforate corals not determinable. Cheilostomatous polyzoa.

(33A). Length 88 millims. Greyish-white, and very porous. Large nodules of *Polytrema planum*, the core almost wholly of this form, with *Amphistegina*, *Heterostegina*, and probably *Cycloclypeus*. Casts of *Pocillopora*, in position of growth; *Cycloseris* (?) and another fungid coral.

(34A, 35A). Total length 161 millims. Greyish, hard, very porous. Same characters as in the preceding; large nodules of *Polytrema*, with other foraminifera. A very neat cast of *Hydnophora microcona*, LAM., apparently in position of growth.

(36A) [691]. Length 97 millims. Whitish, hard, porous dolomite. Under the microscope there is shown a considerable amount of apparently structureless sediment, cemented by crystalline dolomite. Cast of perforate coral, not determinable, the structure replaced by dolomite. *Haddonia*, *Polytrema*, *Amphistegina*, and *Heterostegina*; the structure of these forms partly destroyed. Some detached alcyonarian spicules. *Halimeda*.

(37A) [692]. Length 100 millims. Greyish, hard, porous, and cavernous. About one-half the core consists of an Astræan coral, cf. *Orbicella acropora*, LINN., either as hollow casts or infilled with sediment and crystalline dolomite. The coral perforated by winding annelid (?) tubes with thick walls.

(38A). Length 98 millims. Whitish-grey, hard, porous to compact. Casts of *Orbicella* and *Porites* (?). The larger part of core apparently of fine detrital sediment, with undulating layers of *Polytrema* and *Lithothamnion*. *Amphistegina* and *Heterostegina* very indistinctly shown. Tubes with thick walls.

(39A). Length 105 millims. Greyish-white, hard, porous in places, also cavernous. Large specimen of *Orbicella acropora* (?) as cast. The coral structure has disappeared, the calices, infilled by dolomite, now project as solid fluted pillars with vacant spaces between each. Casts of *Porites* and *Pocillopora*. Corals overgrown by *Polytrema planum*. Cast of shell now occupied by infilled *Cliona* borings, which appear as small rounded beads linked together. *Amphistegina*.

(40A) [693, 694]. Length 88 millims. Greyish, with white patches, hard, only just scratched by knife, mostly compact. Larger part of core consists of cast of *Porites*, now for the most part infilled solid by crystalline dolomite. Also cast of small Astræan; cf. *Orbicella heliopora*, LAM., sp. Outside the corals much opaque sediment, with bands of *Lithothamnion*. Foraminifera indistinct, not numerous; *Gypsina*, *Globigerina* (?), *Amphistegina*, and *Heterostegina*. Tubular borings in coral, now infilled with consolidated mud. *Halimeda*.

(41A). Length 100 millims. Whitish-grey, hard, for the most part, compact, with some cavities. Very little to be seen with lens. Casts of *Pocillopora*, and a perforate coral, *Astræopora* (?). Undulating layers of *Lithothamnion* and *Polytrema* (?), *Amphistegina*.

(42A) [695]. Length 75 millims. Whitish-grey, hard and dense rock. Some small casts of perforate corals, encrusted by *Lithothamnion*. Corals infilled and replaced by crystalline dolomite, and not determinable. Core in part of sedimentary material cemented by dolomite. Patches of *Polytrema*, but they are less prominent than the *Lithothamnion*. *Spiroloculina*, and *Amphistegina*. *Serpula*-tubes. Casts of gastropods.

(43A). Length 113 millims. Greyish-white, mottled, hard and dense. Prominent nodules of *Polytrema planum*, and between these the core is packed with *Amphistegina* and *Heterostegina*. Alcyonarian spicules. Cast of *Pocillopora*.

(44A). Length 110 millims. Whitish, very hard and dense, with occasional small cavities. Large nodules of *Polytrema* and other foraminifera, as in the preceding core. Cast of Astræan coral, not determinable. *Serpula*-tubes.

(45A) [696]. Length 100 millims. Whitish, hard core of the same character as 43A and 44A. Perforate coral surrounded by a thick layer of *Polytrema planum*, and some thin alternating layers of *Lithothamnion*. *Pocillopora*, *Porites*. Corals replaced by crystalline dolomite, and very indistinctly shown. The interspaces between the corals are packed with foraminifera. The following have been determined by Mr. CHAPMAN: *Orbitolites*, *Textularia*, *Globigerina*, rare, *Gypsina*, *Amphistegina*, and *Heterostegina*. Alcyonarian spicules. *Serpula*-tubes. *Cliona*-borings, *Halimeda*.

46A. Length 90 millims. Whitish-grey, hard rock. Cast of *Porites*. Nodules of *Polytrema* and other foraminifera, the same as in the preceding core.

(47A) [697]. Length 110 millims. Whitish-grey, hard and dense rock. Casts of *Pocillopora* and *Porites* enclosed by thick layers of *Polytrema*, with alternating layers of *Lithothamnion*. *Orbitolites complanata*, *Gypsina discus*, *Amphistegina* and *Heterostegina*. Echinid plates. Cast of lamellibranch.

(48A). Length 70 millims. Whitish-grey, hard, in places porous. *Pocillopora*. *Polytrema* nodules and other foraminifera, as in the preceding core.

(49A) [698]. Length 100 millims. Whitish-grey, hard, partly porous, dolomitic limestone. Astræan coral, casts of small *Madrepora* and other corals not determinable, which are overgrown and enclosed by *Polytrema planum*. The corals are almost entirely replaced by crystalline dolomite. The core is mainly composed of foraminifera cemented by dolomite. *Orbitolites* common, *Gypsina*, *Amphistegina*, very numerous, *Heterostegina*. Echinid spines and plates. *Serpula*-tubes, with thick walls showing concentric fibrous layers. *Lithothamnion*, encrusting.

(50A) [583]. Length 104 millims. Whitish-grey, hard, porous, and partly cavernous dolomitic limestone. Several casts of small corals, including an Astræan and specimens of *Turbinaria*, the second time this genus has been noted in the cores. The corals, as usual, encrusted by *Polytrema*. Foraminifera similar to those in preceding core, with the addition of *Carpenteria*.

(51A) [699, 700]. Length 94 millims. Grey, hard, dolomitic limestone, like the preceding. Casts of an Astræan, *Porites* and *Turbinaria*, encrusted by *Polytrema planum*. A considerable number of foraminifera, *Orbitolites*, *Gypsina globulus*, *G. discus*, *Globigerina*, *Amphistegina*, and *Heterostegina*. Echinid spines. Alcyonarian spicules, but little altered in fossilisation; thin sections under the microscope are of a brownish tint, and show the structure of fibres radiating from the central axis.

(52A) [701]. Length 90 millims. Greyish, speckled white, hard, porous, and also cavernous in places. Several corals encrusted by *Polytrema planum*. Casts of *Pocillopora*, an undeterminable Astræan, *Cycloseris*, and *Turbinaria*. The corals are replaced, and the interstices infilled with the crystalline dolomite. Foraminifera, except *Globigerina*, the same as in the preceding core. Cheilostomatous polyzoa.

(53A). Length 52 millims. Dolomitic, like preceding. Casts of small examples of an Astræan coral, also of *Turbinaria*, mostly encrusted by *Polytrema*. The larger part of the core consists of foraminifera, as in 52A.

(54A) [702]. Length 93 millims. Whitish-grey, hard, partly compact, partly porous, dolomitic limestone. Several casts of small *Turbinaria* encrusted by *Polytrema planum* and thin layers of *Lithothamnion*. Larger part of core consists of foraminifera, including *Orbitolites*, *Gypsina*, *Amphistegina* and *Heterostegina*, and with these small detrital organic fragments. Alcyonarian spicules. Echinid spines. Cheilostomatous polyzoa.

Depth from Surface, 763–771 *feet; Distance Bored*, 8 *feet; Total Length of Core Obtained*, 5 *feet* 3 *inches; Numbers of Cores* 55A–73A.

In this 8 feet of the boring the cores are cylindrical, of whitish-grey to grey, hard, partly compact, partly porous, and occasionally cavernous dolomitic limestone. Casts of corals are present throughout, they are indistinct owing to their imperfect preservation, mostly small forms, some are probably in position of growth. They comprise *Seriatopora*, *Pocillopora*, *Goniastræa*, and other indeterminable Astræans, *Galaxea* (?), *Cycloseris*, *Madrepora*, *Turbinaria* and *Porites*. The larger part of the cores as a rule consists of foraminifera and fragmental detrital materials, partly of broken-up foraminifera, and partly of minute fragments of other organisms. These are cemented together by the crystalline dolomitic matrix, which sometimes entirely fills up the interspaces, forming a very dense compact rock, at others, not infrequently in close proximity to the compact portions, the interspaces are only lined by crystals, and the rock is porous. Foraminifera are relatively fewer and less distinct than in the preceding cores, and they are to a certain extent masked by the fine *débris* which constitutes a considerable part of the rock. *Polytrema planum* is less abundant than in preceding cores, the other forms belong to *Orbitolites*, *Globigerina*, *Gypsina*, *Amphistegina*, *Heterostegina*, and in the first two and in one of the lower cores, *Cycloclypeus*. Alcyonarian spicules, echinid spines, *Halimeda*, and *Lithothamnion*, but sparsely represented. No signs of stratification or bedding lines in the cores where the fine material predominates.

Details.

(55A). Length 108 millims. Greyish, hard, for the most part compact and dense rock. Several casts of perforate corals; *Madrepora*, *Turbinaria*, and undetermined forms. Greater part of core consists of foraminifera and fragmental materials. *Orbitolites complanata* common, *Polytrema planum*, *Amphistegina*, *Heterostegina*, and *Cycloclypeus* (?) rare.

(56A). Length 103 millins. Greyish, hard, in part compact, with some cavities where corals have been dissolved away. Several small coral casts are dispersed through the core. *Pocillopora*, an undetermined Astræan, *Cycloseris*, and *Madrepora*. Some of these casts are enclosed by layers of *Polytrema planum*, which in section appear as thick white rings surrounding the partially vacant cast of the coral. Foraminifera and detritus the same as in the preceding. Cheilostomatous polyzoa.

(57A). Length 60 millims. Rock similar to preceding. Small casts of *Pocillopora*, *Madrepora*, and *Porites* (?) very much obscured.

(58A). Length 57 millims. Grey with whitish patches, hard, porous, and with small cavities. Casts of an Astræan, *Madrepora* (?) and other perforate corals, mostly encrusted by thick layers of *Polytrema planum*. *Orbitolites*, *Amphistegina*, and *Heterostegina*, mingled with fragmental materials.

(59A) [584]. Length 97 millims. Whitish-grey, hard, for the most part compact and dense. Several small coral casts, including *Seriatopora*, *Goniastræa* (?) *Madrepora*, and *Turbinaria*, mostly enclosed by layers of *Polytrema*, with some alternating thin layers of *Lithothamnion*. *Globigerina*, *Amphistegina*, and *Heterostegina*. A large amount of fragmental débris. Echinid plates. *Halimeda*. Cemented by crystalline dolomite.

(60A). Length 72 millims. Greyish, hard, half-compact, half-porous, and with small cavities. Casts of *Galaxea* (?), a fungid, and *Turbinaria*. *Orbitolites*, common, *Polytrema*, *Amphistegina*, and *Heterostegina*.

(61A). Length 114 millims. Grey, hard, partly compact, partly porous with a few cavities. Cast of a small *Goniastræa* (?) allied to *G. eximia*, DANA. Greater part of core of detrital materials with *Orbitolites* and *Amphistegina*. Cast of gastropod.

(62A). Length 102 millims. Grey, with white speckles, hard, for the most part compact and dense, with cavities. Cast of *Goniastræa* (?), apparently in position of growth, also cast of *Madrepora*. Greater part of core of fragmental *débris* with foraminifera as in the preceding.

(63A) [703]. Length 33 millims. Grey, hard, compact, similar to preceding. Cast of *Goniastræa* (?) and *Madrepora*, which are enclosed by *Polytrema planum* alternating with *Lithothamnion*. Greater part of core of entire and fragmentary foraminifera cemented by crystalline dolomite. *Globigerina*, rare, *Gypsina discus*, *Amphistegina*, and *Heterostegina*. Fragmentary echinid spines. Many of the detrital fragments are now shown only in outline, their original structures having been replaced by dolomite.

(64A). Length 80 millims. Grey, hard, partly compact, with cavities where corals have been removed. Casts of *Madrepora* and of some other corals not determinable. The compact portion of the core of foraminifera and detritus as in the preceding. Infilled borings of *Cliona*.

(65A). Length 115 millims. Whitish-grey, hard, mostly compact, with some cavities. Imperfect casts of *Pocillopora*, *Fungia*, and *Madrepora*. Small white patches of *Polytrema*. The larger part of the core of foraminifera and detritus, the same as the preceding—little beyond *Amphistegina* is recognisable under a lens. Cast of lamellibranch.

(66A). Length 106 millims. Whitish-grey, dense, with some small cavities. With the exception of a few small casts of *Pocillopora* and *Cyphastræa*, the greater part of the core is detrital like the preceding.

(67A). Length 132 millims., by 57 millims. in diameter. Whitish-grey, hard, minutely porous. Many casts of small corals, *Pocillopora*, an Astræan, *Madrepora*, enclosed by *Polytrema planum* Cast of *Pecten*. Foraminifera not distinguishable with lens. No signs of bedding lines on the slit face of this core.

(68A). Length 43 millims. Rock like preceding. Casts of *Turbinaria* and small *Madrepora*. Core mainly fragmental, with *Amphistegina* and *Polytrema planum*. Cast of lamellibranch.

(69A). Length 73 millims. Whitish-grey, hard, minutely porous. Core nearly entirely of fragmentary materials, with foraminifera and one or two casts of small perforate corals.

(70A). Length 125 millims. Rock of same character as the preceding. Several casts of corals: *Astræa* and *Madrepora contecta*. Greater part of core foraminiferal, with detrital material. *Gypsina*, *Polytrema planum*, and *Amphistegina*. *Lithothamnion*.

(71A) [704]. Length 53 millims. Rock similar to 69A. Cast of small *Madrepora*. Core mainly of detrital material and foraminifera, cemented by crystalline dolomite. *Amphistegina*, *Heterostegina*, and *Cycloclypeus*. Alcyonarian spicules. *Halimeda*.

(72A). Length 67 millims. Greyish, hard, minutely porous, and cavernous, where corals have been in part dissolved out. Casts of a small *Astræa* and undetermined perforate coral. Foraminifera as in the preceding.

(73A). Length 34 millims. Rock similar to the preceding. Mainly of foraminifera, with organic detritus and cast of undetermined coral.

Depth from Surface, 771–781 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 6 *feet* 11 *inches; Numbers of Cores*, 74A–96A.

The cores from this 10 feet of the boring are closely similar in character to those preceding; they consist of greyish to whitish-grey, hard, partly compact, partly porous and cavernous, dolomitic limestone. The rock contains casts of various corals, mostly of small size, but the larger part is composed of entire and fragmentary foraminifera embedded in organic fragmental material and fine sediment. The corals are casts only, very imperfectly preserved; they include *Pocillopora*, *Orbicella* and other Astræan forms, *Fungia*, *Madrepora* and *Turbinaria*. The foraminifera are, as a rule, also considerably altered, and their structural characters are obscured; the most abundant forms are *Polytrema planum* and *Amphistegina Lessonii*; of less frequent occurrence there are *Orbitolites*, *Gypsina* and *Heterostegina*. *Lithothamnion* and *Halimeda*. The lower cores from 86A downwards are somewhat harder and more compact, and the organisms are more clearly shown than in the cores above them.

DETAILS.

(74A). Length 95 millims. Whitish-grey, minutely porous. Almost entirely of foraminifera and detrital materials. *Polytrema* and *Amphistegina*. Only the cast of one small coral noticed.

(75A). Length 110 millims. Rock whitish-grey, similar to preceding. Some small coral casts, not determinable. Mainly of foraminifera and detrital materials. *Orbitolites* and *Amphistegina*. Echinid spine.

(76A) [705]. Length 103 millims. Rock similar to preceding. Casts of a few small corals too far obliterated for determination. A microscopic section shows that the rock consists of fragmentary and entire foraminifera belonging to *Polytrema*, *Gypsina*, *Amphistegina*, and *Heterostegina*. Echinid spines.

(77A). Length 122 millims. Rock of same general characters as preceding. Casts of small perforate corals, overgrown by *Polytrema planum* Mainly fragmental, with the same foraminifera as in 76A.

(78A, 79A). Total length 156 millims. Cylindrical cores of greyish, hard, minutely porous rock, with occasional cavities. Casts of small corals, not sufficiently preserved for determination. *Polytrema*. *Amphistegina* and *Heterostegina* are the only foraminifera distinguishable with a lens.

(80A). Length 107 millims. Greyish, hard, very fine grained, minutely porous to compact. Apparently altogether of foraminifera and organic detritus. Only forms recognisable with a lens are *Amphistegina* and *Heterostegina*.

(81A). Length 98 millims. Core of same character, and with the same foraminifera as the preceding. A single cast of *Fungia*.

(82A). Length 86 millims. Greyish-white, hard, minutely porous. Casts of several small corals, including *Madrepora*. Greater part of core foraminiferal and detrital. *Polytrema planum*, *Amphistegina*, very numerous, and *Heterostegina*.

(83A). Length 55 millims. Grey, hard, fine-grained, mostly compact. Cast of *Pocillopora*. Alcyonarian spicules. *Serpula*-tubes.

(84A). Length 56 millims. Core like preceding. Cast of small *Pocillopora*. Alcyonarian spicules. *Amphistegina*. Cast of lamellibranch.

(85A). Length 64 millims. In part grey, in part white, hard, porous, with cavities where corals have been dissolved out. Casts of *Madrepora* and other corals not determinable. *Polytrema*,

Amphistegina, *Heterostegina*. *Lithothamnion*. Less fragmental material in this than in preceding cores, and the organisms can be more distinctly seen.

(86A) [706]. Length 90 millims. Greyish-white, hard, compact, with a few cavities. Several casts of corals, including *Fungia*, the width of the core (57 millims.), also perforate corals, *Madrepora* and *Montipora* (?); their structures are replaced by dolomite, whilst the interstices are infilled with sediment, and they are enclosed by alternating layers of *Polytrema planum* and *Lithothamnion*. The foraminifera include *Orbitolites*, *Gypsina discus*, *Amphistegina*, and *Heterostegina*. Plates of echinids. Fragments of *Lithothamnion*. Joints of *Halimeda*, showing their tubular structure very distinctly under the microscope, calling to mind that of *Girvanella* from the Silurian rocks. Alcyonarian spicules. The organisms are cemented by crystalline dolomite.

(87A). Length 25 millims. Greyish-white, hard, generally similar to preceding. Cast of *Madrepora* (?).

(88A) [707]. Length 42 millims. Mottled white and grey, hard, porous. Mainly of coral casts, now replaced by crystalline dolomite, and penetrated by borings of *Cliona* and other organisms, so that their original characters cannot be determined. The borings are infilled with consolidated mud. *Polytrema* and *Amphistegina*.

(89A). Length 100 millims. Mottled grey and white, hard, dense dolomite. Many small perforate corals, including *Madrepora contecta*, enclosed by thick layers of *Polytrema planum* and *Lithothamnion*. Between the corals *Amphistegina* and *Heterostegina*. *Halimeda*-joints.

(90A). Total length 240 millims. Greyish-white, hard, compact to porous, with some cavities. Core largely of coral casts enclosed by *Polytrema planum* and *Lithothamnion*. *Orbicella*, cf. *O. acropora* and *Madrepora*, many casts not determinable. *Amphistegina* and *Heterostegina*. *Halimeda*.

(91A). Length 136 millims., diameter 57 millims. Rock of the same character as preceding. Casts of small Astræan, *Madrepora*, and others not determinable. About half the core foraminiferal; *Polytrema* and *Amphistegina*, very numerous. Casts of lamellibranchs.

(92A) [708]. Length 100 millims. Mottled, grey, and white, hard, dense, partly porous, partly compact, with a few cavities. Many casts of corals, *Pocillopora*, two kinds of Astræan corals and *Madrepora*. The corals replaced by dolomite are dissolved; the interstices either infilled by sediment or crystalline. *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. *Lithothamnion* in undulating layers. *Halimeda*. Casts of lamellibranchs. *Serpula*.

(93A). Length 75 millims. Whitish-grey, hard, mostly compact, but with a large patch where the rock is porous. Several coral casts, one an Astræan, also *Turbinaria* and others not determinable, showing only infilled borings of *Cliona*. Corals overgrown by *Polytrema* and *Lithothamnion*. Core packed with foraminifera, principally *Amphistegina Lessonii*. Alcyonarian spicules.

(94A) [709]. Length 30 millims. Rock similar to preceding. Cast of Astræan coral replaced by dolomite, and the interstices filled in with sediment. Alcyonarian spicules; thick layers of *Polytrema planum* and *Lithothamnion*, with foraminiferal and other detrital materials cemented by crystalline dolomite.

(95A). Length 78 millims. Rock of same character as 91A. Casts of perforate corals; *Madrepora* and *Montipora* (?). Corals small, and as usual encrusted by *Polytrema* and *Lithothamnion*. *Amphistegina*, very numerous.

(96A). Length 100 millims. Whitish-grey, hard, porous rock. With the exception of two small examples of *Pocillopora* and *Madrepora*, the core is foraminiferal and fragmental, the predominant form being *Amphistegina Lessonii*. Casts of gastropods. *Halimeda*-joints.

*Depth from Surface, 781–790 feet; Distance Bored, 9 feet; Total Length of Core Obtained, 7 feet 10 inches; Numbers of Cores, 97*A–122A.

The cores are cylindrical; they consist of whitish-grey, mottled with white, and occasionally speckled, undulating layers of dolomitic rock, generally similar to the preceding. The rock is hard, it can be scratched with a knife, but not readily, (H = 4); is generally compact, but with occasional cavities and small hollows. The whitish banded portions, for the most part of encrusting *Polytrema* and *Lithothamnion*, are of a softer character than the grey portions of the rock. The cores are formed mainly of casts of corals and foraminifera, with fine detrital materials. The corals are more numerous than in the preceding cores; in some cases they are estimated to form one-third to one-half the rock. They principally belong to *Pocillopora*, *Cœloria*, *Astræa*, *Goniastræa*, *Madrepora*, *Astræopora*, and *Porites*. The corals are, in part, replaced by crystalline dolomite, and their interstices infilled by fine consolidated sediment; often, however, the original structure has been removed, and the spaces are now empty. Some of the corals appear to be in their position of growth. For the most part they are small forms.

The larger part of the rock still consists of foraminifera and detritus cemented by crystalline dolomite. The foraminifera include *Orbitolites*, *Textularia*, *Placopsilina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. *Carpenteria* occurs in patches. The walls are removed, and only their casts traversed by the infilled canals remain; *Polytrema planum* is a very prominent feature of the rock. Alcyonarian spicules are of common occurrence, and one specimen of *Lobophytum* was noticed. *Serpula*-tubes. *Halimeda*, fairly preserved, and *Lithothamnion*. The consolidated detrital materials and fine sediment, as seen in microscopic sections, consist of broken-up foraminifera, and fragments of *Lithothamnion*, with other minute particles of organisms, which cannot be determined.

DETAILS.

(97A, 98A). Total length 186 millims. Whitish-grey, hard, compact, dolomite, with cavities. Casts of small forms of *Madrepora* and *Porites* (?). Greater part of the core consists of foraminifera and detrital materials, *Amphistegina*, very numerous. *Polytrema*. *Serpula*. Casts of lamellibranchs.

(99A, 100A). Total length 187 millims. Whitish-grey, hard, generally compact and dense. Some porous areas and small cavities. Several casts of *Madrepora* and other perforate corals, altered beyond recognition; these serve as the nuclei of *Polytrema* and *Lithothamnion*, which encrust them with white concentric layers. Somewhat more than half the core consists of foraminifera and minute fragments cemented by dolomite. Casts of gastropods.

(101A) [710]. Length 113 millims. Greyish-white, mottled and speckled, partly compact, partly porous. Lower part of core entirely of cast of *Porites*, cf. *P. arenosa*, ESPER, sp. Coral structure replaced by crystalline dolomite, and the interstices infilled with the same in part, and in part empty. The foraminifera include *Orbitolites*, *Textularia*, *Calcarina*, *Polytrema*, *Amphistegina* and *Heterostegina*. Alcyonarian spicules; groups of *Serpula*-tubes. *Halimeda*, showing structure. Fragments of *Lithothamnion* in the detrital materials.

(102A) [711, 712]. Length 111 millims. Banded white and grey, hard and dense rock. Casts of

Madrepora contecta and *Porites*. About one-third of this core consists of coral casts and the investing *Polytrema planum*. Foraminifera, as in the preceding, with the addition of *Carpenteria*. Alcyonarian spicules, common. Numerous minute detrital fragments, but too much altered for determination.

(103A). Length 129 millims., diameter 58 millims. Greyish-white, mottled, with occasional small cavities. Somewhat less than half the core consists of coral casts; *Pocillopora*, an Astræan, *Madrepora* and *Porites* (?). The corals encrusted with *Polytrema* and some *Lithothamnion*. Foraminifera and detrital materials form almost exclusively the lower half of the core.

(104A) [713]. Length 81 millims. White and grey, hard, some small cavities. *Cœloria*, replaced by crystalline dolomite and the interstices filled in with consolidated sediment. About two-thirds the core of nodular, very evenly laminated, *Lithothamnion*, with numerous perforations. Alcyonarian spicules. *Amphistegina*. Stellates of ascidians in the sediment.

(105A) [714]. Length 96 millims. Mottled white and grey, porous in places. Casts of *Madrepora* and an Astræan coral, with other forms not determinable. Foraminifera abundant, their structure imperfectly preserved. *Orbitolites, Carpenteria, Calcarina, Gypsina vesicularis*, var. *discus*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina* are shown in the microscopic section. Detached spicules of alcyonarians, and a fragment of *Lobophytum*. *Halimeda*, *Lithothamnion*.

(106A). Length 151 millims. Greyish-white, mottled, hard, porous in places, with some small cavities. Several casts of small forms of *Madrepora*, *Astræopora*, and other corals, with a large amount of encrusting *Polytrema* and some *Lithothamnion*. Larger part of core packed with foraminifera; *Orbitolites*, *Carpenteria*, *Amphistegina* and *Heterostegina* can be distinguished with a lens. *Halimeda*-joints.

(107A) [715]. Length 52 millims. Grey, hard, porous, cavernous. Core almost entirely consists of a cast of *Astræopora*, the coral structure mostly removed and the interstices filled in with consolidated sediment or with crystalline dolomite. Alcyonarian spicules. *Gypsina vesicularis*, var. *discus*, *Amphistegina* and *Heterostegina*. *Halimeda*.

(108A) [716, 717]. Length 90 millims. Grey, hard, compact to porous. About one-third of core consists of coral casts; *Cœloria*, cf. *C. dædalea*, Ellis and Sol., apparently in position of growth, small *Madrepora* and *Astræopora*. The remaining part of the core of foraminifera and detrital material, *Orbitolites*, *Polytrema*, *Amphistegina* and *Heterostegina*. *Lithothamnion*.

(109A). Length 96 millims. Mottled grey and white, hard, partly compact, partly porous. *Cœloria*, cf. *C. dædalea*, surrounded by thick undulating layers of *Polytrema planum* and *Lithothamnion*. Branching *Madrepora*. More than half the core of coral growth and the encrustations over it, the rest of foraminifera and detrital material, as in the preceding, together with patches of *Carpenteria* casts.

(110A). Length 127 millims. Mottled greyish-white, hard, mostly compact, with small cavities. Casts of *Cœloria*, like the preceding. The greater part of the core of foraminifera and minute fragments, with white nodular patches of *Polytrema* and *Lithothamnion*. *Orbitolites*, *Carpenteria* (casts), *Amphistegina* and *Heterostegina*.

(111A). Length 89 millims. Greyish, hard, porous and cavernous, where corals are present. *Madrepora contecta*, structure poorly shown. Thick layers of *Polytrema* and *Lithothamnion*. Foraminifera very indistinct.

(112A, 113A) [718]. Total length 134 millims. Whitish-grey, speckled, hard, compact generally, but cavernous where corals have been removed. Casts of *Madrepora contecta*, also of *Goniastræa*; the coral structure replaced by crystalline dolomite, the interspaces partly occupied by consolidated sediment. More than half the core of foraminifera and minute detrital fragments of organisms—some now replaced by dolomite. *Orbitolites*, *Textularia*, *Calcarina*, *Gypsina vesicularis*, var *discus*, *Polytrema miniaceum*, *Amphistegina* and *Heterostegina*. Alcyonarian spicules, echinid spines. Casts of gastropods. *Halimeda*, branching *Lithothamnion*.

(114A, 115A) [719]. Total length 150 millims. Greyish-white, mottled, hard, compact, with fissure-like hollows. Casts of the same form of *Goniastræa* as in the preceding, also of *Madrepora* and undulating

layers of *Montipora* (?) Foraminifera as in the preceding, with the addition of *Placopsilina* and of *Polytrema planum*. Alcyonarian spicules. Echinid spines. *Lithothamnion*, *Halimeda*.

(116A, 117A, 118A). Total length 246 millims. Greyish-white, speckled, hard, partly compact, partly porous, with irregular hollows. Several casts of *Madrepora*, surrounded by white layers of *Polytrema planum* and *Lithothamnion*. Larger part of the cores of foraminifera and minute detrital fragments, very little recognisable with a lens beyond casts of *Carpenteria*. Rock very crystalline.

(119A). Length 75 millims. Greyish, speckled, hard, dense. With the exception of one or two small undeterminable casts of corals, the core consists of foraminifera and fragmental detritus, cemented by crystalline dolomite.

(120A) [585]. Length 162 millims. Greyish, speckled white, hard, mostly compact. A few casts of a small *Madrepora*, now filled up with dolomite. Casts of gastropods and lamellibranchs. By far the larger part of the core of foraminifera, with worn fragments of organisms, now dolomitised beyond recognition. Foraminifera also much altered. *Orbitolites*, *Calcarina*, *Gypsina vesicularis*, var. *discus*, and *Gypsina*, sp., *Polytrema miniaceum*, *P. planum*, *Amphistegina* and *Heterostegina*, can be distinguished in microscopic sections. *Halimeda*-joints, not uncommon. Echinid plates. Branching *Lithothamnion*.

(121A, 122A). Total length 64 millims. Rock in character like the preceding. Cast of Astræan coral, cf. *Astræa denticulata*, ELLIS and SOLANDER, and of a smaller form as well.

Depth from Surface, 790–798 *feet*; *Distance Bored*, 8 *feet*; *Total Length of Core Obtained*, 7 *feet* 5 *inches*; *Numbers of Cores*, 123A–144A.

Cores cylindrical, of greyish-white, mottled with undulating bands of white, and also speckled, dolomitic limestone. Generally hard, like the preceding, but in some cores the whitish portions, comprising principally *Lithothamnion* and some of the fragmental materials, have undergone a change, and are now soft and powdery. For the most part the rock is compact and dense, but in places where the foraminifera and detrital materials have been only partially cemented by crystalline dolomite it is porous. The rock is not infrequently cavernous, due to the partial removal of corals. Corals as casts are generally present; some cores are mostly composed of them, while in others only one or two small forms are to be found. They are in the same condition as noticed previously; the structure is either dissolved or replaced by crystalline dolomite, whilst the interstices are now either crystalline, or infilled with hardened sediment. The corals include *Pocillopora*, *Seriatopora*, *Orbicella*, and *Madrepora contecta*, largely composing one of the cores (134A), and *Porites*. The foraminifera are less prominent; the same forms are present as in the cores immediately preceding. Alcyonarian spicules are of common occurrence, and one piece of *Lobophytum* is present. Fairly large casts of gastropods. The most notable feature of the cores is the great development of *Lithothamnion*, both as encrusting corals and as nodular branches. The encrusting foraminifer, *Polytrema planum*, is also present, but very subordinate to the calcareous alga. *Halimeda* also occurs. The organic contents of these cores call to mind the cores of reef rock in the upper portion of the boring.

DETAILS.

(123A). Length 93 millims. Grey, speckled, hard and compact, except where coral occurs. Nearly

two-thirds of the core consists of an Astræan coral (?) *Orbicella*, probably in position of growth. The coral is surrounded by nodular and encrusting *Lithothamnion*. Remainder of core consists of foraminifera and fragmental material; but little can be distinguished under a lens.

(124A) [720]. Length 93 millims. Greyish-white, banded, partly compact, partly porous, and with small cavities. Cast of meandriform coral (?) *Cœloria*. About one-third of the core of *Lithothamnion*, in white, thick, undulating layers, very dense and opaque, but when reduced to thin sections the structure is fairly well shown; rows of oval conceptacles are present. *Calcarina*, *Gypsina vesicularis*, var. *discus*, *Polytrema planum*, *Amphistegina*, and *Heterostegina*. Alcyonarian spicules. Echinid spines. Gastropod casts.

(125A). Length 68 millims. Greyish-white, mottled, hard, very cavernous. Core mainly of thick, white layers and branches of *Lithothamnion*, like the preceding. Casts of small perforate corals, filled up with the dolomitic matrix. Foraminifera and *débris*, as in the last core.

(126A, 127A, 128A). Total length 234 millims. Grey, speckled, hard, generally compact, dolomite, with occasional cavities where gastropods have been dissolved out. Casts of branching *Seriatopora*, and other small corals not determinable. Corals overgrown by *Lithothamnion*. The cores are nearly entirely of foraminifera and minute detrital materials; the only forms recognisable under a lens are *Orbitolites* and *Amphistegina*. *Serpula*.

(129A). Length 98 millims. Grey, hard, dense, with several small cavities. Casts of small corals, enclosed by *Lithothamnion*, and infilled by crystalline matrix. Larger part of core consists of foraminifera and detrital material.

(130A). Length 126 millims., by 58 millims. in diameter. Grey, hard, compact for the most part, in places porous and cavernous. Core mainly of coral casts; Astræan, *Madrepora*, and *Porites*, cf. *P. arenosa*.

(131A) [721]. Length 107 millims. Whitish-grey, speckled, hard, mostly compact and dense, central portions slightly cavernous. Casts of small perforate corals, *Madrepora* (?) and *Montipora* (?); they are replaced by dolomite, and encrusted by *Lithothamnion*. About two-thirds of the core consists of foraminifera and fragmental material. *Calcarina*, *Gypsina vesicularis*, var. *discus*, *Polytrema planum*, and *Heterostegina*. Alcyonarian spicules, but little altered. Echinid spines. *Serpula*-tubes in groups. Cast of small *Echinus*.

(132A). Length 98 millims. Greyish, mottled rock, hard, mostly compact, with some small cavities. Several casts of small forms of *Madrepora* and *Montipora* (?), encrusted by *Lithothamnion*. Foraminifera and minute fragments, same as in previous core. *Serpula*, branching *Lithothamnion*.

(133A) [722]. Length 140 millims. Greyish, mottled, mostly compact, with occasional cavities. Largely of casts of corals, enclosed by layers of *Lithothamnion*, the casts for the most part infilled with crystalline dolomite, whilst in some there are infilled borings of *Cliona*, &c. *Pocillopora*, *Madrepora contecta*, *Montipora* (?). *Orbitolites*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Alcyonarian spicules. Echinid spines, their structure almost obliterated. *Halimeda*. Casts of gastropods.

(134A) [723]. Length 85 millims. White, with a few greyish spots, porous, the white portions are soft, incoherent, can be scratched with the finger nail, whilst the grey are hard and compact. The entire core, except one corner, is a mass of *Madrepora contecta*, the coral is replaced by crystalline dolomite, whilst the interstices are in part empty, in part filled with white, opaque, detrital material. In upper end of core cast of Astræan coral, but little shown. Casts of gastropods. Nodules of *Lithothamnion*. Alcyonarian spicules. *Amphistegina*.

(135A) [724]. Length 176 millims. Whitish-grey, mottled and speckled, partly compact, partly porous, hard, some cavities where gastropods and corals have been dissolved out. Cast of *Madrepora contecta* and other perforate corals replaced by dolomite. Fragment of *Lobophytum* 23 millims. long by 8 millims., as shown in section, with the spicules in position. They are for the most part unaltered, and retain their fibrous structure; in some instances, however, their interiors have been

replaced by crystalline dolomite. Foraminifera numerous, embedded in a fine-grained sediment; *Textularia rugosa*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Gastropod casts, one 30 millims. in length by 26 millims. wide at base. *Halimeda*, *Lithothamnion*.

(136A) [725]. Length 92 millims. Greyish-white, mottled, hard, mostly porous. Cast of *Madrepora* (?), in part hollow, in part filled in with crystalline dolomite, and enclosed by *Lithothamnion*. Other small coral casts not determinable. Infilled borings of *Cliona*. Foraminifera and detritus. *Calcarina*, *Gypsina*, *Polytrema miniaceum*, and *Amphistegina*. Alcyonarian spicules, echinid spines. *Lithothamnion*, with the structure well preserved.

(137A). Length 113 millims. Grey, mottled, hard, compact, with porous patches. General characters like the preceding core; a few casts of small corals, filled with crystalline dolomite; thick, undulating layers of *Lithothamnion*, and an agglomerated mass of foraminifera and minute detritus. *Polytrema* and *Amphistegina*. Echinid spines.

(138A). Length 88 millims. Greyish-white, compact to porous, very cavernous, where corals have been removed. Core traversed by casts of a branching *Pocillopora*, showing a mould of the calices in the walls of the cast. Foraminifera commingled in coarse detrital fragments. *Orbitolites*, *Gypsina*, *Polytrema*, and *Amphistegina*. *Lithothamnion*.

(139A, 140A) [726]. Total length 202 millims. Mottled, grey and white, hard, partly compact, partly porous. Core mainly of thick, undulating layers of *Lithothamnion*, showing structure, and interspaces now filled with crystalline dolomite, where corals appear to have been removed. A small quantity of *Polytrema planum*, alternating with the *Lithothamnion*. *Orbitolites*, *Gypsina inhærens*, *Amphistegina*. Branching *Pocillopora*; Alcyonarian spicules. *Halimeda*-joints.

(141A). Length 100 millims. Whitish-grey, mottled and speckled. About half the core of layers of *Lithothamnion*, the rest of foraminifera and detritus. *Pocillopora* and *Madrepora*.

(142A). Total length 199 millims. Greyish-white, hard, porous, with small cavities. Many casts of small corals; *Pocillopora*, which has been extensively bored by *Cliona*, and *Madrepora contecta*, partly overgrown by *Polytrema planum*. *Lithothamnion*, in comparatively small amount. Foraminifera but little shown.

(143A, 144A). Total length 119 millims. Whitish-grey, mottled, mostly compact, with small cavities. Casts of small corals, replaced by crystalline dolomite and very obscurely shown. *Pocillopora* and *Madrepora*. *Polytrema planum*.

Depth from Surface, 798–804 *feet*; *Distance Bored*, 6 *feet*; *Total Length of Core Obtained*, 4 *feet* 1 *inch*; *Numbers of Cores*, 145A–156A.

Cores cylindrical, of greyish, greyish-white, mottled, hard, dolomitic rock, mostly compact, but very cavernous, the hollows arising from the removal of corals. The cores largely consist of casts of small corals, many apparently in position of growth. The most persistent is *Pocillopora*; with the exception of one specimen of *Orbicella* (?), the other forms are perforates, belonging to *Madrepora*, *Porites* (?), and *Montipora* (?). They are all in an unfavourable state of preservation, the structure being either entirely removed or replaced by crystalline dolomite, and they are frequently traversed by a network of infilled casts of *Cliona* and other organisms, which remain after the coral itself has been dissolved away. Foraminifera are hardly distinguishable under a lens, the forms recognised belong to *Carpenteria*, *Calcarina*, *Gypsina*, and *Amphistegina*. *Polytrema* encrusts the corals, often alternating with *Lithothamnion*, which

is abundant. Alcyonarian spicules, echinid spines, and joints of *Halimeda* are included in the fragmental detritus.

DETAILS.

(145A, 146A). Total length 174 millims. Greyish-white, hard dolomite, with several cavities. Casts of *Pocillopora*, *Madrepora*, *Porites* (?) or *Montipora*, overgrown by *Polytrema planum* and *Lithothamnion*. Infilled casts of *Cliona*. *Amphistegina*. Casts of lamellibranchs.

(147A). Length 130 millims. Mottled, greyish-white, hard rock, very cavernous. Casts of *Pocillopora* and *Madrepora*, for the most part solidly infilled and replaced by the dolomitic matrix; the *Pocillipora*, however, is more often dissolved away, leaving only a mould of the calices. *Amphistegina*.

(148A). Total length 243 millims. Whitish-grey, hard, compact to porous, and very cavernous. Casts of *Pocillopora* and *Madrepora* in the same condition as in the preceding. Very little to be seen under a lens in the areas not occupied by corals. The infilled casts of *Cliona* very well shown.

(149A) [727]. Length 177 millims. Grey, mottled, hard, with numerous cavities. Casts of *Pocillopora* and *Madrepora*, which are encrusted with layers of *Polytrema planum* and *Lithothamnion*. Interstices of the corals infilled with consolidated sediment. *Carpenteria*, *Calcarina*, *P. miniaceum*, and *Amphistegina*. Alcyonarian spicules. Echinid spines. In the detrital material, fragments of *Lithothamnion* and *Halimeda*, and pieces of organisms now replaced by crystalline dolomite.

(150A 151A) [728]. Total length 190 millims. Mottled, greyish-white, hard, porous in places, and very cavernous. Cores mainly of casts of *Pocillopora*, with thick, white, undulating layers of *Lithothamnion*. *Gypsina inhærens*.

(152A, 153A, 154A). Total length 120 millims. Rock of same character as preceding. Mainly of *Pocillopora* and thick undulating layers of *Lithothamnion*. In 154A a cast of a small *Orbicella* (?), cf. *O. orion*, DANA.

(155A, 156A). Total length 190 millims. Greyish, hard, partly compact, partly porous, with large cavities. Casts of *Pocillopora* and *Madrepora*. In the greater part of these cores the organic remains are either quite obliterated or replaced by crystalline dolomite, in which only whitish grains can be seen with a lens.

Depth from Surface, 804–810 feet; Distance Bored 6 feet: Total Length of Core Obtained, 5 feet 1 inch; Numbers of Cores, 157A–174A.

Cores cylindrical, of whitish, whitish-grey, partly mottled, dolomitic limestone; hard (H = 4), partly compact, partly porous, in places cavernous, but not nearly to the same extent as in the cores preceding. The cores on the whole are principally of casts of corals, apparently in position of growth: they are badly preserved, and usually enclosed by growths of *Polytrema planum* and *Lithothamnion*. The corals include *Pocillopora*, *Seriatopora*, *Cœloria*, Astræan not determined, *Madrepora*, *Turbinaria*, *Montipora*, and *Astræopora*. The areas between the corals are filled with fragmental materials; amongst these are foraminifera, alcyonarian spicules, echinid spines, casts of Gastropods, *Serpula*, *Halimeda*, and in the finer sediment the minute stellate spicules of *Leptoclinum* can be recognised. The organisms are cemented by crystalline dolomite.

DETAILS.

(157A). Length 91 millims. Whitish-grey, porous, hard dolomite, with small cavities. The core is traversed by a branching *Pocillopora*, apparently in position of growth. The corallites are either solid or

hollow, and have the tabulæ preserved. Casts of a small *Madrepora*, solidly infilled with crystalline dolomite. *Amphistegina*. *Halimeda*.

(158A, 159A). Total length 141 millims. Whitish-grey, mottled, mostly compact, with occasional cavities. Casts of *Pocillopora*, an Astræan, and indistinct perforate corals, some solidly infilled with the crystalline matrix. The corals are enclosed by layers of *Lithothamnion*. Foraminifera not distinguishable with a lens.

(160A). Length 52 millims. Greyish, speckled, hard, partly porous. Apparently detrital in character, solidly infilled with the dolomitic matrix, only small, white patches of *Lithothamnion* distinguishable. Casts of large gastropod, and of a lamellibranch.

(161A) [729]. Length 147 millims. Greyish-white, mottled, porous, with some cavities. More than half the core filled with a branching *Pocillopora*, in position of growth, similar to that in 157A. In the lower half of the core a small Astræan and *Montipora* (?) filled with the crystalline dolomite. Foraminifera in fine sedimentary material containing *Leptoclinum* stellate spicules, now replaced. *Orbitolites*, *Globigerina*, *Calcarina*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, *Heterostegina*. Echinid spines. Alcyonarian spicules. Casts of gastropods. Encrusting *Lithothamnion*, *Halimeda*.

162A. Length 132 millims. Whitish-grey, hard, partly compact, partly porous dolomite. The upper third of the core consists of a cast of *Cœloria*; in the lower portion, *Madrepora*, with other small perforate corals, the characters nearly obliterated. Rest of core foraminiferal and fragmental. *Polytrema planum*, and *Amphistegina*. *Lithothamnion*.

(163A) [729a]. Length 178 millims. Mottled whitish-grey, hard, partly compact, partly porous, with occasional small hollows. Core principally consisting of casts of corals either porous or solidly infilled with crystalline dolomite. *Pocillopora* common, *Madrepora*, *Astrœopora*, and *Montipora* (?). The corals overgrown by *Polytrema planum* and *Lithothamnion*. *Amphistegina*. Areas of fine detrital mud with numerous stellate spicules of *Leptoclinum*.

(164A). Length 100 millims. Rock of similar character to the preceding. *Pocillopora*, *Madrepora*, *Porites*, *Polytrema planum*, and *Amphistegina*. *Lithothamnion* as nodules and encrusting layers.

(165A) [730]. Length 107 millims. Whitish-grey, hard, partly compact, partly porous dolomite. Casts of *Madrepora* and *Turbinaria*, encrusted by thick layers of *Polytrema planum* and *Lithothamnion*. About half the core detrital and foraminiferal. *Amphistegina*. Alcyonarian spicules; echinid spines; *Serpula*. Casts of gastropods.

(166A). Length 84 millims. Greyish, speckled, hard, compact, with porous areas. Core apparently altogether of foraminifera and fragmental material. *Amphistegina*. *Lithothamnion*.

(167A). Length 80 millims. Greyish, hard, in part porous, where corals are present. *Madrepora* cast, enclosed with thick layers of *Polytrema planum*, and some *Lithothamnion*. Foraminifera not distinguishable by lens.

(168A). Length 74 millims. Grey, speckled, hard, porous. With the exception of a small cast of *Pocillopora*, the core is detrital, with foraminifera, but only *Amphistegina* can be distinguished. Alcyonarian spicules. Echinid spines. *Lithothamnion*.

(169A, 170A, 171A). Total length 171 millims. Whitish-grey, hard, porous, and very cavernous. Casts of *Pocillopora*, *Seriatopora*, and *Madrepora*. The corals overgrown by *Polytrema planum* and *Lithothamnion*. *Amphistegina*. Coarse detrital materials, the interspaces but partially infilled with crystalline dolomite.

(172A, 173A). Total length 86 millims. Grey, hard, porous rock. Only alcyonarian spicules recognisable.

(174A) [731]. Length 77 millims. Mottled grey and white, hard, compact to porous. Several casts of small corals; *Fungia*, *Madrepora*, and other perforates enclosed by *Polytrema* and *Lithothamnion*. *Textularia rugosa*, *Gypsina inhœrens*, *G. discus*, *Amphistegina Lessonii* numerous, and *Heterostegina*. Alcyonarian spicules, echinid spines. Casts of gastropods.

Depth from Surface, 810–815 *feet; Distance Bored*, 5 *feet; Total length of Core Obtained*, 3 *feet* 6 *inches*; *Numbers of Cores*, 175A–186A.

Cores cylindrical, greyish-white, often banded or speckled, hard, partly compact and dense, partly porous and cavernous dolomite. Corals are generally present, but now frequently replaced and infilled solid with crystalline dolomite, and their characters mostly obliterated. This applies more particularly to the perforate forms; in the Astræan corals the structures are often dissolved and not infilled with dolomite, but even under these conditions they can only approximately be determined. They are included in *Astræa*, *Goniastræa*, *Cycloseris*, *Madrepora*, and *Porites*. The corals are, as usual, encrusted by layers of *Polytrema* and *Lithothamnion*.

A considerable amount of fragmental detritus with foraminifera is present in the cores. The most abundantly represented are *Orbitolites*, *Carpenteria*, *Amphistegina*, and *Heterostegina*. Alcyonarian spicules, echinid spines, and in the finer sediment, stellates of *Leptoclinum* are present. *Halimeda*-joints.

DETAILS.

(175A). Length 80 millims. Greyish-white, hard, mostly compact, with occasional cavities. Largely of a perforate coral, *Madrepora* or *Porites*, encrusted by *Polytrema planum* and some *Lithothamnion*. Detrital materials, with *Amphistegina* and *Heterostegina*, from the rest of the core.

(176A, 177A). Length 72 millims. Greyish-white, hard, very cavernous. Faint indications of corals, replaced by dolomite. Core mainly detrital, with *Amphistegina* and *Heterostegina*. Alcyonarian spicules.

(178A). Length 173 millims., diameter 59 millims. Greyish-white, mottled, hard, mostly compact with occasional hollows. Casts of *Madrepora* and *Montipora* are fairly numerous, they are mostly infilled with crystalline dolomite, and encrusted by *Polytrema* and *Lithothamnion*. Cast of *Goniastræa* (?). *Amphistegina*. *Halimeda*. *Cliona* borings.

(179A, 180A). Total length 140 millims. Mottled, whitish-grey, hard, porous in part. Cast of simple Astræan coral, young form (?), and *Porites*, encrusted by *Polytrema planum*. *Amphistegina*.

(181A). Length 122 millims. Greyish, banded white, hard, partly porous with elongate flattened hollows. Core mainly of corals casts. *Goniastræa* (?) and *Astræopora*. Detrital material between the corals, with *Orbitolites*, *Polytrema*, and *Amphistegina*. *Lithothamnion*.

(182A). Length 111 millims. In character similar to preceding. Core largely of casts of corals, *Goniastræa* (?) as in the preceding core, and undulating layers of *Montipora* infilled with the crystalline matrix and encrusted by *Polytrema*. *Orbitolites*, *Amphistegina*.

(183A) [732, 733]. Length 82 millims. Mottled, greyish-white, hard, mostly compact, with some hollows. Cast of *Goniastræa* (?) replaced by dolomite, and *Porites*, with its interspaces infilled with fine, opaque consolidated sediment. In this material there are numerous stellates of *Leptoclinum*. The foraminifera comprise *Ophthalmidium*, *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema planum*, *Planorbulina*, *Amphistegina*, *Heterostegina*. Alcyonarian spicules; echinid spines. *Halimeda*-joints.

(184A) [734]. Length 66 millims. Rock like preceding. Casts of *Madrepora* replaced by crystalline dolomite and the interspaces filled with fine, consolidated sediment. *Gypsina*, *Amphistegina*, *Heterostegina*. Alcyonarian spicules. Echinid spines. *Halimeda*.

(185A) [735]. Length 98 millims. Mottled grey, hard, cavernous, where corals have been removed, elsewhere mostly compact. Casts of *Cycloseris*, and indications of other corals now replaced by dolomite.

The matrix is a fine-grained dolomite with numerous hollows which are lined by crystals with a light brownish exterior banding. *Orbitolites*, other foraminifera as in the preceding.

(186A). Length 113 millims. Greyish-white, hard, generally compact, with a few cavities. Casts of an Astræan, *Madrepora*, and *Porites*. *Amphistegina*.

Depth from Surface, 815-822 *feet; Distance Bored*, 7 *feet; Total Length of Core Obtained*, 4 *feet* 5 *inches* ; *Numbers of Cores*, 187A–197A.

Cores cylindrical, whitish-grey, generally hard dolomitic rock, like the preceding. Mostly compact, with occasional cavities. In some of the lower cores, a change has taken place in the whitish portion of the rock, which has become much softer, whilst the brownish portion in contact with it retains its hardness. Casts of small Astræan and perforate corals are scattered in the cores, but they are so dolomitised that they can hardly be recognised, and they are fewer in proportion to the foraminiferal and detrital contents of the core than in the preceding cores. *Madrepora* and *Astræopora* can be distinguished, and also a small specimen ot *Millepora*. Foraminifera are numerous, but beyond *Polytrema* and *Amphistegina* they can only be seen in microscopic sections. Casts of gastropods and lamellibranchs. *Serpula*.

DETAILS.

(187A) [736]. Length 131 millims. Whitish-grey, mostly compact, hard, with occasional hollows. Casts of *Astræopora*, replaced by dolomite, also a small *Millepora* (shown in microscopic section). Greater part of core consists of detrital materials with foraminifera. *Orbitolites*, *Planorbulina*, *Polytrema planum*, *Amphistegina*, *Heterostegina*. Alcyonarian spicules; echinid spines. Casts of gastropods.

(188A). Length 180 millims. Mottled whitish-grey, hard, mostly compact with a few small cavities. Casts of small corals fairly numerous. *Astræa*, *Madrepora*, and others not determinable. The corals encrusted by *Polytrema* and *Lithothamnion*. *Amphistegina*. Casts of gastropods and lamellibranchs. *Serpula*.

(189A). Length 200 millims. Whitish-grey, hard, mostly compact. A few small casts of *Madrepora* enclosed by *Polytrema planum*. The greater part of core consists of fine detrital materials with foraminifera, scarcely any beyond *Amphistegina* distinguishable with a lens. Echinid spines. Casts of gastropods.

190A. Length 105 millims. Rock similar to preceding. Casts of *Madrepora*. *Amphistegina*. Echinid spines.

(191A). Length 102 millims. Greyish-white, hard dolomite. Core broken up into several pieces. Casts of small corals, characters obliterated.

(192A, 193A). Total length 240 millims. Whitish-grey, hard dolomite, fairly compact, with irregular hollows. Casts of undeterminable corals. *Polytrema*, *Amphistegina*. Echinid spines, *Lithothamnion*.

(194A). Length 101 millims. Grey and white rock intermingled, the white softer and more porous. Mainly foraminiferal and detrital. Foraminifera numerous. A very rotund form of *Amphistegina* occurs here and in some of the preceding cores. Large echinid spines, well preserved, some showing a brownish tint.

(195A, 196A). Total length 181 millims. Like preceding, grey and white areas intermingled, some of the latter sufficiently soft to be scratched by nail. Contents of cores same as preceding.

(197A) [737]. Length 84 millims. White and greyish areas as in preceding, the greyish, a hard crystalline dolomite replacing coral, the white portion consists mainly of the foraminiferal and fine detrital material, and is comparatively soft. Cast of perforate coral, not determinable, encrusted by *Polytrema planum*. *Globigerina*, *Carpenteria*, *Planorbulina*, *P. miniaceum*, and *Amphistegina*. Large, well preserved echinid spines. Pores lined by rhombohedral crystals of dolomite.

Depth from Surface, 822–833 *feet; Distance Bored*, 11 *feet; Total Length of Core Obtained*, 7 *feet* 11 *inches; Numbers of Cores*, 198A–215A.

The cores in this portion of the boring are for the most part cylindrical, in one or two instances, however, the rock has broken up into fragments, now rounded by the drill. The cores are mainly of a whitish to cream-tinted or greyish-white, porous, dolomitic limestone, for the greater part soft; though it does not as a rule yield to the finger nail, it is readily scratched by a knife. Other portions are much harder, only scratched by a knife under pressure; both hard and soft portions are found in the same piece of core. The pores and larger cavities are lined by deposits of dolomitic limestone, in very thin successive layers, which in section have the appearance of agate or stalactitic structure. There is also an efflorescence on the exterior and split surfaces of some of these cores which yet further obscures their characters. Corals are only occasionally present and then merely as indistinct casts or impressions of the outer surface; small examples of *Pocillopora*, *Madrepora*, and *Astræopora* are the only forms noticed. The rock, as seen in microscopic sections, consists principally of a fine sediment with foraminifera and minute fragments of organisms. The foraminifera belong for the most part to *Carpenteria*, *Polytrema*, which often forms nodules, *Amphistegina*, and *Heterostegina*, while *Globigerina*, *Planorbulina*, and *Calcarina* are of less frequent occurrence. *Carpenteria* in these cores has the walls preserved and shows the minute structure favourably. The cores further contain large echinid spines, casts of lamellibranchs and gastropods, *Halimeda* and *Lithothamnion*.

DETAILS.

(198A). Length 33 millims. Several rubbly pieces of greyish-white, hard dolomitic rock, in which only obscure casts of corals and *Amphistegina* can be distinguished.

(199A). Length 110 millims. Cylindrical, whitish, soft and porous, efflorescent, with some hard grey areas where coral casts have been infilled with crystalline dolomite. *Madrepora* (?). Core mainly of detrital sediment with *Carpenteria*, numerous echinid spines, and small lamellibranchs and gastropods.

(200A). Length 92 millims. Core similar to preceding.

(201A). Length 71 millims. Whitish, hard, mostly compact. Cast of perforate coral filled in with dolomite. Core mainly of fine sedimentary material with *Polytrema planum*, *Amphistegina*, and numerous echinid spines, some retaining a pinkish tint and obtusely triangular in transverse section.

202A. Length 308 millims. White to greyish-white, banded, porous, in part soft, in part hard. Efflorescence in places. Several irregular cavities in which corals were probably present, but only one, an impression of *Pocillopora*, could be distinguished. The core mainly of detrital materials with undulating layers of *Polytrema planum*, *Amphistegina*, and *Heterostegina*. Echinid spines and casts of gastropods.

(203A, 204A) [586]. Total length 163 millims. Whitish, chalky-looking, porous, dolomitie rock, in places sufficiently soft to be scratched by the finger nail, and with occasional cavities, which may originally have contained corals, but there are no indications left. The core is principally of fine sediment, containing *Globigerina*, *Planorbulina*, *Carpenteria*, *Polytrema planum*, and *Amphistegina*. Echinid spines.

(205A) [738]. Length 68 millims. Greyish-white, banded, hard, cavernous rock. In the central portion of the core, cast of an upright branching *Madrepora* replaced by dolomite, with the coral interstices infilled

with fine sediment. The coral overgrown by thick layers of *Polytrema planum* and thin alternating layers of *Lithothamnion*, both showing minute structure in microscopic section.

(206A). Length 195 millims. Mottled grey and white, hard, porous to compact. Several casts of corals filled up with dolomite; only in one instance, a *Madrepora*, recognisable. Core mainly of detrital material, with foraminifera, of which only *Amphistegina* can be distinguished. Echinid spines.

(207A). Length 33 millims. Whitish, porous, with surface efflorescent. Cast of small *Stylophora* (?), rest of core detrital, like preceding.

(208A) [739]. Length 248 millims. Whitish, with grey bands and nodular areas, porous, moderately hard. Several indistinct casts of corals, perhaps *Madrepora* (?); the casts are overgrown by thick layers of *Polytrema planum* and some *Lithothamnion*. Greater part of cores of sedimentary materials, with foraminifera and echinid spines.

(209A). Length 50 millims. Whitish-grey, mottled, hard, compact to porous. Cast of coral overgrown by *Polytrema planum*.

(210A). Length 348 millims. Grey and whitish, speckled in places, hard and porous. Indistinct traces of coral in the grey harder portions of the core, which, as usual, are surrounded by layers of *Polytrema*. Only *Madrepora* can be distinguished. Core mainly of detrital materials. *Amphistegina* and echinid spines can be made out with a lens. The nearly complete obliteration of the corals in these cores seems to be due to the agate-like secondary deposition of crystalline dolomite.

(211A, 212A). Total length 128 millims. Whitish, soft to moderately hard, porous. Cast of *Madrepora*. Greater part of cores of fine fragmentary organic materials, with foraminifera, echinid spines, and casts of lamellibranchs and gastropods.

(213A) [740]. Length 228 millims. Whitish-grey, hard, mottled, compact to porous, dolomitic limestone. Casts of corals infilled with crystalline material, and overgrown by layers of *Polytrema planum*. The only coral distinguishable is *Astræopora*. Larger part of core of detrital materials with *Carpenteria* and *Amphistegina*; the former with the wall structure preserved. Echinid spines, *Halimeda*.

(214A, 215A). Total length 230 millims. Rock similar to preceding. Obscure traces of corals, surrounded by layers of *Polytrema*. Rest of core detrital.

Depth from Surface, 833–844 *feet; Distance Bored*, 11 *feet; Total Length of Core Obtained*, 10 *feet* 6 *inches; Numbers of Cores*, 216A–234A.

Cores cylindrical, of a whitish to cream-tinted, hard ($H = 4$), mostly compact, fine-grained rock. The upper cores to 224A, at 838 feet, are similar to those preceding in being to a considerable extent dolomitic, but below this level the proportion of magnesian carbonate is considerably less, and the rock appears to be mainly of crystalline calcite. The organic constituents of the upper and lower cores are very much of the same character. Corals seem to form only a small part of the rock; they are, as before, nearly entirely obliterated by the infilling of dolomitic limestone. Only small forms of *Stylophora*, *Astræa*, *Orbicella* (?), and another Astræan coral, with *Madrepora* and *Astræopora*, have been distinguished, and these are overgrown by *Polytrema planum* and *Lithothamnion*. The larger part of the cores consist of foraminifera and fragmental materials, cemented by dolomite or calcite. Where this latter mineral in part replaces the dolomite at the level of about 838 feet, the foraminifera are better preserved, and more favourably shown in microscopic sections. The forms represented are given below; the principal change is the reappearance of

Orbitolites in considerable numbers. Alcyonarian spicules and echinid spines are generally distributed. A few casts of gastropods. *Lithothamnion* and *Halimeda*.

DETAILS.

(216A). Length 273 millims. Creamy-white, hard, compact to porous, dolomitic limestone. With the exception of two brownish patches, where corals may have been originally, this solid core is composed of fine detrital material with foraminifera. Comparatively little can be distinguished with a lens; the only forms recognised are *Orbitolites* and *Polytrema planum*, also echinid spines.

(217A) [741]. Length 175 millims. Whitish-grey, hard, mostly compact. A few indications of small corals, but the structure is nearly entirely obliterated, so that no determination is possible. *Polytrema planum*, showing structure, surrounds the spaces where corals have been. Core almost entirely of detrital materials and foraminifera belonging to *Globigerina*, *Carpenteria*, *Polytrema miniaceum* and *Amphistegina*. Alcyonarian spicules, echinid spines, fragments of *Lithothamnion*. The materials cemented with crystalline dolomite.

(218A, 219A). Total length 202 millims. Rock similar to preceding. A single cast of coral noted; the core of minute fragmental materials and foraminifera. *Orbitolites complanata* is the only form recognisable with a lens.

(220A, 221A). Total length 285 millims. Cream-coloured, hard, minutely porous, with occasional cavities lined by crystalline dolomite. A few traces of small corals, one an Astræan. *Orbitolites* abundant, *Amphistegina*. Large echinid spines. Casts of gastropods.

(222A) [742]. Length 93 millims. Whitish, hard, compact, with porous areas, and with one or two cavities where corals have probably been dissolved out. The core appears to be partly dolomitic, partly of calcite. A microscopic section shows that the rock consists of fragmentary and entire foraminifera in fine detrital material. *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina inhærens*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Alcyonarian spicules, echinid spines. Casts of gastropods.

(223A). Length 54 millims. Rock similar to preceding. Casts of *Stylophora* and *Madrepora*, encrusted by *Polytrema planum*. *Orbitolites*. Echinid spines.

(224A) [743]. Length 106 millims. Whitish, hard, mostly compact calcite, with some dolomite. One or two hollows in which corals may have been. Mainly of foraminifera in fine detrital material, their structures well shown in microscopic section. The same forms as in Core 222A, with the addition of *Spiroloculina* and *Textularia*. Alcyonarian spicules numerous, showing their normal fibrous structure, echinid spines. Casts of small gastropods. Small fragments of *Lithothamnion*; other fragments, now crystalline, which may originally have been of corals. *Halimeda* (?).

(225A) [587]. Length 212 millims. Whitish-grey, hard, minutely porous to compact, partly dolomitic limestone. One or two hollows. Indications of corals in places, but now replaced by crystalline matrix. Core nearly altogether foraminiferal, the same forms present as in 222A. *Orbitolites* and *Calcarina* are very numerous. Echinid spines. *Lithothamnion*.

(226A) [744]. Length 151 millims., 57 millims. in diameter. Whitish-grey, hard rock, like preceding, with occasional cavities. Several small corals very indistinctly shown. An Astræan, *Madrepora*, and *Astræopora* (?). The same foraminifera as in 222A. Alcyonarian spicules numerous; echinid spines. Numerous fragmentary foraminifera and other organisms. *Lithothamnion*. *Halimeda* seldom. Banded stalactitic structure lining the cavities.

227A. Length 260 millims. Whitish-grey, hard, compact to minutely porous. Traces of small corals enclosed by undulating layers of *Lithothamnion*. Core mainly of foraminifera and fine detritus, like the preceding, but the only forms distinguishable with a lens are *Orbitolites* and *Amphistegina*. Echinid spines.

(228A). Length 286 millims. Whitish-grey, hard, compact to minutely porous, very uniform, dense rock. Closely similar in character to the preceding core. Very little to be distinguished with a

lens; the rock almost entirely foraminiferal and detrital; the pores are lined with the mammillary crystalline material.

(229A) [745]. Length 149 millims. Greyish-white, hard, partly compact, partly porous, very uniform, dense rock, similar to the preceding core. A microscopic section shows the same foraminifera and detrital materials cemented by calcite (?) as in the cores above. *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema planum*, *Amphistegina* and *Heterostegina*. Alcyonarian spicules. Echinid spines. *Lithothamnion*.

(230A) [746]. Length 223 millims. Greyish-white, compact mostly, very uniform, dense rock, apparently a limestone, only in part dolomitic. Corals not recognised. Very little to be seen with a lens; a microscopic section from the lower half of the core shows numerous alcyonarian spicules in good preservation, mingled with *Polytrema miniaceum*, *Amphistegina*, and *Heterostegina*. Echinid spines.

(231A). Length 221 millims. Greyish, mostly compact, hard, dolomitic limestone. Obscure traces of corals, now replaced by the crystalline mammillated deposit, a small *Orbicella* (?) and *Madrepora*. Hardly anything to be made out with a lens, the structures being replaced by crystalline material. *Lithothamnion* (?).

(232A). Length 105 millims. Grey, with white patches, very hard, mostly compact rock, some small corals, for the most part replaced with solid crystalline dolomite. *Astræa* (?), *Madrepora* (?), also cast of *Millepora*, which has not been replaced, and is better preserved than the ordinary corals. Foraminifera not recognisable with lens. *Lithothamnion* occurs as white patches. Cast of lamellibranch.

(233A, 234A). Total length 245 millims. Greyish-white, mottled and speckled, compact to porous, dense. Indications of corals, now replaced by crystalline materials; they appear to have formed a considerable part of these cores. The coral areas enclosed by *Lithothamnion*. Very little to be seen beyond a few specimens of *Orbitolites*, *Amphistegina*, alcyonarian spicules, and echinid spines.

Depth from Surface, 844–853 *feet; Distance Bored*, 9 *feet; Total Length of Cores Obtained*, 7 *feet* 2 *inches; Numbers of Cores*, 235A–248A.

Cores cylindrical, of grey, greyish-white, and whitish limestone, in part dolomitic. The rock hard, generally compact, but in places porous and cavernous. For about 2 feet in the upper part of this boring the rock contains numerous casts of small corals, in the remaining 7 feet the rock consists principally of fine detrital material, with foraminifera, and only occasionally casts of small corals. The corals are very unfavourably preserved, the only forms recognised belong to *Pocillopora*, *Astræa*, *Orbicella*, and *Madrepora*. Alcyonarian spicules are plentiful, and generally distributed throughout the cores. The foraminifera include *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. *Halimeda* and *Lithothamnion*.

DETAILS.

(235A) [747]. Length 77 millims. Grey, hard, mostly compact, dolomitic limestone. Cast of an Astræan and of some perforate corals, now infilled with the crystalline matrix. Greater part of core of minute organic detrital materials, with *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina inhærens*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Numerous alcyonarian spicules, less favourably preserved than hitherto; some are partially replaced by the crystalline matrix. *Halimeda* and *Lithothamnion*.

(236A). Length 138 millims. Grey, hard, minutely porous. In lower part of core cast of *Madrepora contecta*. Alcyonarian spicules very numerous. But little to be seen with lens.

(237A) [748]. Length 28 millims. Grey, hard, porous; the pores and hollows lined with mammillated crystalline deposit. Cast of *Astræa*; the structure replaced by crystalline dolomite, and the interstices infilled with fine consolidated sediment.

(238A). Length 250 millims. Greyish-white, hard, porous, with some cavities. Cast of *Orbicella* (?), occupying about one-third of the core, also of *Madrepora* and other corals. They are now replaced by crystalline material, and very indistinct. *Polytrema planum*, *Amphistegina* (?). *Lithothamnion*.

(239A). Length 256 millims. Greyish-white, hard, minutely porous, and with some hollows. Mainly of casts of small corals; Astræan and branching *Madrepora*. Corals frequently enclosed by layers of *Polytrema planum*. *Amphistegina*, *Lithothamnion* (?).

(240A). Length 266 millims. Greyish-white, hard, minutely porous, and cavernous in places. In the upper part of the core there are many casts of small corals, but too indistinct for determination. The lower part appears to be entirely of minute detritus, with foraminifera. *Polytrema planum*, *Amphistegina*. Echinid spines. Small gastropods. *Lithothamnion*.

(241A). Length 77 millims. Whitish, moderately hard, porous, rough, showing efflorescence. Mainly of detrital material and foraminifera, with casts of *Pocillopora* and *Montipora* (?). *Amphistegina*. Casts of small lamellibranchs and gastropods.

(242A). Length 317 millims. Cylindrical core, partly whitish, porous, rough to feel, efflorescent, and partly grey, smooth and hard, with hollows lined by crystalline deposit. Both kinds of the core principally of foraminiferal and minute detrital materials; the only organisms recognised with a lens are *Amphistegina*, echinid spines, and *Halimeda*-joints.

(243A). Length 93 millims. Mottled, greyish-white, hard, mostly compact, with occasional cavities. With the exception of two or three casts of small perforate corals, the core consists of foraminifera and consolidated organic detritus. *Polytrema planum*, *Amphistegina*. Echinid spines. *Halimeda*.

(244A, 245A). Total length 146 millims. Whitish, speckled, hard, mostly compact, with a large longitudinal hollow, which appears to have been originally occupied by a perforate coral. The rest of the core similar to the preceding, of detrital material with great numbers of *Amphistegina*.

(246A) [749]. Length 230 millims. Whitish, hard, partly compact, partly with minute pores. Very little can be distinguished under a lens, but a thin microscopic section shows that the rock is nearly altogether of a very fine organic detrital sediment, with some casts of small corals replaced by crystalline material, and with little more than the borings of parasitic organisms infilled by the sediment now remaining. The foraminifera include *Globigerina*, not common, *Carpenteria* (in fragments), and *Amphistegina*. Echinid spines. *Halimeda*.

(247A, 248A). Length 286 millims. Greyish-white, hard, mostly compact dolomitic limestone. With the exception of a few obscure casts of corals, these cores are of consolidated detrital materials and foraminifera, similar to the preceding.

Depth from Surface, 853–866 *feet; Distance Bored*, 13 *feet; Total Length of Cores Obtained*, 10 *feet* 11 *inches; Numbers of Cores*, 249A–276A.

Solid cylindrical cores of whitish, greyish-white, generally hard, dolomitic limestone. The rock is, for the most part, dense and compact, but some portions are porous, rather softer than the compact grey portions, and occasionally efflorescent. Some cores, moreover, are largely cavernous, the hollows are lined with crystalline material, showing in section the agate-like disposition of the layers already referred to. The greater part of these cores, to a level of about 864 feet (Core No. 269A), apparently consist of foraminifera in a fine detrital organic sediment now consolidated and

cemented by crystalline dolomite. There is hardly a trace of a coral to be seen on the slit surfaces of the cores, but there are good reasons for regarding the cavernous hollows as having originally been occupied by corals, and in addition to these, the cores contain portions of solid crystalline material, mostly without structure, which likewise were probably at first corals, which have now been altered and replaced by the secondary crystallisation. In microscopic sections the crystalline portions can be seen with traces of coral casts in them, and they are often surrounded by layers of *Polytrema* and *Lithothamnion*, which originally grew over the corals. In the lower cores, corals, belonging to *Astræa*, are largely developed.

Foraminifera are generally present; the commoner forms are *Polytrema* and *Amphistegina*, and they are pretty well the only ones recognisable with a lens; in microscopic sections the following genera are also shown:—*Orbitolites*, *Peneroplis*, *Bolivina*, *Globigerina*, *Planorbulina*, *Carpenteria*, *Gypsina* and *Heterostegina*. Echinid spines are numerous, alcyonarian spicules, and *Leptoclinum* stellates. *Lithothamnion*.

DETAILS.

(249A). Length 90 millims. Whitish-grey, mottled, hard, mostly compact. Trace of perforate coral. Nearly altogether detrital, with *Polytrema*, *Amphistegina* and echinid spines.

(250A) [750]. Length 223 millims. Whitish-grey, mottled, partly porous, partly compact; occasional cavities. The core consists of consolidated organic sediment, with numerous foraminifera belonging to *Peneroplis*, *Globigerina*, *Planorbulina*, *Carpenteria*, *Gypsina inhærens*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Echinid spines.

(251A). Length 248 millims. Whitish-grey, hard, mostly compact, with occasional hollows. The greater part of detrital materials with *Amphistegina*. Alcyonarian spicules. Echinid spines.

(252A–255A). Total length 352 millims. Cylindrical cores of whitish-grey, hard, generally compact, dolomite, with cavities lined with the crystalline deposit; the same material also fills up areas in the cores where corals have been present. Mostly of detrital sediment with foraminifera and echinid spines.

(256A, 257A). Total length 270 millims. Cores of the same whitish-grey rock as the preceding, very cavernous in places, in section showing a large infilling of the banded agate-like crystalline deposit. Only echinid spines to be seen with a lens.

(258A) [751]. Length 97 millims. Whitish, hard, compact to porous, with some cavities. Traces of coral. Core nearly altogether of fine organic sediment, but becoming crystalline. The foraminifera shown in a microscopic section belong to *Orbitolites*, *Globigerina*, *Planorbulina*, *Carpenteria*, and *Polytrema planum*. Alcyonarian spicules and echinid spines. Casts of *Leptoclinum* stellates.

(259A). Length 90 millims. Grey and white areas, the latter porous and not so hard as the grey portions. Only echinid spines recognisable under a lens.

(260A). Length 160 millims. About half the core greyish, hard, crystalline, with cast of perforate coral, (?) *Astræopora*, the other part of the core whitish, efflorescent, porous, apparently of detrital sediment with echinid spines.

(261A). Length 128 millims. Principally whitish, speckled, moderately hard, porous dolomite, efflorescent; in the lower portion greyish, crystalline, with traces of perforate coral. The white part of the core of detrital materials, with echinid spines and casts of small gastropods. *Lithothamnion*.

(262A). Length 104 millims. Core of grey and white portions irregularly intermingled; large hollow lined by crystalline deposit. Casts of small perforate corals. Echinid spines numerous. *Orbitolites*.

(263A). Length 86 millims. Greyish-white, hard, with numerous small hollows from which organisms

have been removed. Echinid spines very numerous. Core mainly of detrital materials, with some grey crystalline areas where corals have been replaced.

(264A, 265A). Total length 304 millims. Cores whitish-grey, with whitish porous areas, hard. Large hollows, lined by crystalline deposit. Rock of detrital materials; the only forms recognisable with a lens are echinid spines.

(266A). Length 110 millims. Greyish-white, banded, compact, with a few cavities. Greater part of the core consists now of the secondary crystalline dolomite, showing in section the agate-like layers; this has probably replaced corals, of which there are some obscure traces. Only echinid spines to be seen with a lens.

(267A) [588]. Length 101 millims. Whitish-grey, hard, generally compact. Now largely crystalline, with some foraminifera and echinid spines. *Bolivina*, *Carpenteria*, and *Heterostegina*.

(268A) [752]. Length 204 millims. Whitish-grey, mottled, hard, compact, with a few small hollows. Casts of corals seen in thin section under the microscope, encrusted by layers of *Polytrema planum* and *Lithothamnion*. *Gypsina* and *Polytrema miniaceum*. Echinid spines.

(269A, 270A) [753]. Total length 205 millims. Whitish-grey, hard, with small cavities. More than half the core consists of a cast of a coral, partly replaced by dolomite; it appears to belong to *Astræa*. Other corals were originally present, judging from the areas now infilled with crystalline material.

(271A) [754]. Length 97 millims. Greyish, hard, partly compact, with large hollows. Core mainly of coral casts of the same Astræan as in the preceding. Echinid spines, somewhat triangular in section.

(272A–276A). Total length 343 millims. Greyish-white, hard, with large hollows. Rock mainly of the secondary crystalline dolomite with agate-like bands in section which has replaced corals. The only organisms to be recognised with a lens are echinid spines and encrusting layers of *Lithothamnion*.

Depth from Surface, 866–874 *feet; Distance Bored*, 8 *feet; Total Length of Core Obtained*, 5 *feet* 4 *inches; Numbers of Cores*, 277A–296A.

Cores cylindrical, of greyish and greyish-white, hard, dolomitic rock, partly compact, partly porous, oftentimes with large irregular cavities lined with the crystalline deposit. In the upper cores the rock mainly consists of this secondary dolomitic material, which has apparently replaced corals and other organisms so that hardly any are distinguishable under a lens. In the cores from 283A (about 870 feet) downwards, coral casts constitute the larger part of the rock; they are often indistinct, the structure having been replaced by dolomite, whilst the interstices are filled in with fine consolidated organic sediment. The corals belong to *Pocillopora*, *Astræa*, *Goniastræa*, *Fungia* (?) *Madrepora*, including *M. contecta*, and *Porites*. Foraminifera are less prominent, they include *Orbitolites*, *Globigerina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Detached alcyonarian spicules and pieces of *Lobophytum* occur. Echinid spines, *Serpula*, together with *Lithodomus* (boring into corals), *Halimeda* and *Lithothamnion*.

DETAILS.

(277A, 278A). Total length 192 millims. Greyish, hard, dolomitic rock, with large hollows, lined with crystalline material, showing in section banded agate-like layers. Probably the cores were originally of corals, but only faint indications of an Astræan coral are now distinguishable.

(279A, 280A). Total length 186 millims. Rock of the same character as the preceding but less cavernous. Only imperfect casts of an Astræan coral with *Amphistegina* and echinid spines can now be recognised.

(281A) [755]. Length 116 millims. Whitish-grey, hard, cavernous core, of dolomite similar to preceding. Imperfect cast of an Astræan and cast of *Porites arenosa* (?) ESPER, overgrown by *Polytrema planum*. Interspaces between the corals filled with detrital materials containing *Amphistegina*, echinid spines, and alcyonarian spicules in good preservation.

(282A, 283A) [756]. Total length 104 millims. Greyish-white, banded, hard, cavernous, dolomite. Casts of *Astræa*, replaced by crystalline material, also of *Fungia* (?). Corals overgrown by *Polytrema planum*, and occasionally perforated by *Lithodomus*. Corals apparently form the larger part of the cores; the interspaces between are filled with organic detrital materials containing *Globigerina*, *Calcarina*, *Gypsina*, and *Amphistegina*, also with alcyonarian spicules.

(284A–286A). Total length 181 millims. Greyish-white, hard, compact to porous, cavernous. Casts of the same *Astræa* as in the preceding, also of *Porites arenosa*. *Polytrema planum* and *Amphistegina*. *Serpula*. *Halimeda*-joints.

(287A) [757]. Length 72 millims. Greyish-white, hard, for the most part compact. Casts of small corals replaced by crystalline dolomite; the only form recognisable is *Porites*. Alcyonarian spicules. *Orbitolites*, *Carpenteria*, *Gypsina discus*, *Polytrema planum*, and *Amphistegina*. Nodular *Lithothamnion*.

(288A) [758]. Length 97 millims. Core similar to preceding. Casts of *Madrepora contecta* and *Porites arenosa*. Core mainly of corals, now replaced by crystalline dolomite, and the interspaces with fine organic detritus; they are encrusted by *Polytrema planum*. Alcyonarian spicules. *Carpenteria*, *Calcarina*, *Gypsina inhærens*, *Amphistegina*.

(289A–291A) [759]. Total length 156 millims. Greyish-white, hard, dolomitic limestone, with occasional hollows, in one instance (291A) about one-fourth the core is hollow. Faintly shown casts of Astræan corals and *Porites*. Portion of stem of *Lobophytum*. The spicules in the stem are without any definite orientation, they range to 2·5 millims. in length by 0·54 millim. in thickness, their structure is well shown in a microscopic section. The stem is partly overgrown by *Polytrema planum*. *Orbitolites*, *Carpenteria*, and *Amphistegina*.

(292A, 293A). Total length 159 millims. The rock is of the same character as the preceding. Casts of *Porites* and of other perforate corals too imperfect for recognition. *Polytrema*, *Amphistegina*. Echinid spines. Nodular pieces of *Lithothamnion*.

(294A, 295A). Total length 174 millims. Whitish-grey, with some spots of softer rock in the lower part of 295A. *Pocillopora*, *Astræa*, *Goniastræa*, *Madrepora*, and other small perforate corals partly filled by matrix, partly as porous casts. Alcyonarian spicules. Detrital materials, with *Orbitolites*, *Gypsina*, *Polytrema*, and *Amphistegina*. *Halimeda*. *Lithothamnion*.

(296A). Length 155 millims. Banded grey and white, hard, compact, but with porous spaces. The grey bands of crystalline dolomite consist of *Porites*, apparently in position of growth; the intermediate bands are partly of layers of *Polytrema planum*, partly of consolidated detrital materials, with *Orbitolites* and *Amphistegina*. Casts of gastropods.

Depth from Surface, 874–881 *feet; Distance Bored*, 7 *feet; Total Length of Core Obtained*, 6 *feet* 2 *inches; Numbers of Cores*, 297A–310A.

Cores cylindrical, of whitish to whitish-grey, hard, dolomitic limestone, partly compact, partly porous, with small hollows, but, as a rule, not cavernous. The cores are largely composed of corals, apparently in position of growth; the coral structures mostly replaced by crystalline dolomite, and the interspaces either crystalline or of detrital sediment; they are better preserved than in the cores above. The genera recognised are *Pocillopora*, *Astræa*, *Goniastræa*, *Cœloria*, *Madrepora*, *Turbinaria* (?),

Astræopora, *Porites* very common. *Lobophytum* and detached alcyonarian spicules are present. The corals are largely overgrown by *Polytrema planum* and *Lithothamnion*. Fine detrital sediment with *Orbitolites*, very abundant; *Planorbulina*, *Carpenteria*, *Gypsina*, *Nonionina*, and *Amphistegina*. Echinid spines and casts of gastropods fill the spaces between the corals. Infilled borings of *Cliona*.

DETAILS.

(297A, 298A). Total length 160 millims. Greyish and spotted grey and white, hard, porous rock, with some small hollows. Casts of small corals, not determinable, encrusted by nodular growths of *Polytrema planum*, *Orbitolites* common, *Amphistegina*. Echinid spines. Casts of gastropods. *Lithothamnion*.

(299A). Length 71 millims. Core similar in character to the preceding. Largely of coral casts. *Pocillopora* and *Porites arenosa*. *Orbitolites* and *Amphistegina*. Large echinid spines.

(300A). Length 211 millims. Grey and white areas, hard, with small hollows. Mainly of corals, replaced by crystalline dolomite, apparently in position of growth. *Pocillopora*, *Astræa* (?), *Cœloria*, *Porites arenosa*. *Orbitolites*, *Polytrema planum*, *Lithothamnion*.

(301A). Total length 356 millims. Greyish-white, hard, compact generally, with small hollows and occasional cavities, where corals have been removed. Corals numerous; *Pocillopora*, *Astræa*, *Madrepora*, and *Porites*. *Lobophytum*. *Orbitolites*, *Amphistegina*. *Lithothamnion* abundant. Casts of gastropods.

(302A). Length 102 millims. Core similar to preceding. Casts of *Cœloria*, the same as in 300A, *Madrepora*, and *Porites*. Foraminifera, as in the preceding.

(303A). Length 158 millims. Greyish-white, hard, porous, with small hollows, partly occupied by casts of corals. Core mainly of corals, belonging to *Pocillopora*, *Astræa*, *Fungia* (?), *Madrepora*, and *Porites*. The areas between the corals are filled with fine detrital materials and foraminifera. *Orbitolites*, *Calcarina*, and *Amphistegina*. Infilled borings of *Cliona*. *Lithothamnion*.

(304A). Length 167 millims. Mottled greyish-white, hard, for the most part compact, but in some coral areas porous. Largely of corals, apparently in position of growth. *Cœloria*, *Madrepora*, *Porites*, *Astræopora*. Some of the corals encrusted by *Polytrema planum*. *Orbitolites* (numerous), *Gypsina*, and *Amphistegina*. Nodular *Lithothamnion*.

(305A) Length 80 millims. Rock similar to preceding. Mainly of corals; *Cœloria* and *Goniastræa* (?). *Polytrema* encrusting corals, *Orbitolites* and *Amphistegina*.

(306A) [760]. Length 57 millims. Greyish, hard, dolomitic rock, with some white portions soft, so as to be scratched with finger nail. Traces of perforate corals replaced by crystalline dolomite. Much opaque detrital material, containing *Orbitolites*, *Carpenteria*, *Planorbulina*, *Polytrema planum*, *Nonionina*, and *Amphistegina*. Nodular *Lithothamnion*.

(307A) [761]. Length 104 millims. Mottled greyish-white, hard, partly porous, partly compact, with small hollows. Casts of *Astræa* (?), *Porites*, and *Turbinaria*. Alcyonarian spicules. *Orbitolites*, *Polytrema*, *Amphisteyina*. Casts of gastropods. Echinid spines. Branching and fragmentary *Lithothamnion*.

(308A). Length 74 millims. Rock similar to preceding. Casts of *Astræa* (?) and of small perforate corals, nearly obliterated. *Orbitolites*, *Calcarina*, and *Amphistegina*. Casts of gastropods.

(309A) [762, 763]. Length 210 millims. Whitish, with some grey spots, hard, mostly compact. Casts of *Madrepora*, *Astræopora*, and small perforate corals. Alcyonarian spicules. Fine consolidated detrital materials, with *Orbitolites*, *Textularia*, *Planorbulina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema planum*, growing in thick layers, *Amphistegina*, and *Heterostegina*. Nodular *Lithothamnion*. Large echinid spines.

(310A)]. Length 110 millims. Rock similar to preceding. Cast of Astræan coral, *Madrepora*, and small perforate corals. Core mainly of detrital materials, with foraminifera. *Polytrema planum* very abundant. *Orbitolites*, *Amphistegina*. Echinid spines. Gastropods.

Depth from Surface, 881–890 *feet*; *Distance Bored*, 9 *feet*; *Total Length of Core Obtained*, 7 *feet* 11 *inches*; *Numbers of Cores*, 311A–325A.

Cores cylindrical, of mottled grey and white, hard, dolomitic limestone, in part porous, in part compact, with occasional hollows where corals have been dissolved out. In some of the cores the banded crystalline dolomite lines the cavities and replaces the corals. The cores are mainly of corals, as poorly preserved casts, some evidently in position of growth. The following genera have been recognised: *Pocillopora*, *Seriatopora*, *Cœloria*, *Astræa*, *Goniastræa*, *Fungia* (?), *Cycloseris*, *Madrepora*, and *Porites*. *Millepora*, *Lobophytum*, and detached alcyonarian spicules also occur. With the exception of *Cœloria* and *Porites arenosa*, most of the corals are small forms. The areas between the corals are occupied with fine detrital materials and numerous foraminifera belonging to *Orbitolites*, common, *Planorbulina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Nonionina*, *Amphistegina*, and *Heterostegina*. Echinid spines, stellate spicules of *Leptoclinum* as casts. *Serpula*. Borings of *Cliona*. *Lithothamnion*.

DETAILS.

(311A) [764]. Length 338 millims. Whitish-grey, generally hard, but with white, softer areas, compact to porous, with small hollows. Mainly of coral casts, *Seriatopora*, *Astræa*, *Madrepora*, and other small perforate corals, frequently overgrown by *Polytrema planum*. The foraminifera belong to *Orbitolites*, *Calcarina*, and *Amphistegina*. Alcyonarian spicules, *Cliona* borings. *Serpula*. Casts of gastropods. *Lithothamnion*.

(312A) [765–768]. Length 427 millims. Greyish-white, hard, partly compact, partly porous, with some hollows where gastropods and corals have been removed. Banded crystalline dolomite has infilled and replaced many of the corals. *Cœloria*, *Astræa*, *Madrepora*, and small perforate corals. *Millepora*, *Lobophytum*, and detached alcyonarian spicules. Foraminifera, as in the preceding, with the addition of *Gypsina* and *Heterostegina*. Casts of gastropods. *Lithothamnion*.

(313A). Length 125 millims. Greyish-white, hard, compact to porous, with hollows lined by crystalline dolomite. *Madrepora* (?), *Porites arenosa*. *Orbitolites*. *Serpula*. *Lithothamnion*.

(314A, 315A) [769, 770]. Total length 138 millims. Greyish-white, hard, porous. The cores consist mainly of a cast of *Porites arenosa*, apparently in position of growth. Also *Madrepora* (?) and other small corals indistinctly shown. *Orbitolites* (abundant), *Carpenteria*, *Gypsina globulus*, *Polytrema planum*, and *Amphistegina*. Small gastropods.

(316A, 317A). Total length 178 millims. Greyish-white, hard, partly porous, partly compact, with occasional hollows. Numerous casts of corals; *Pocillopora*, *Cœloria*, *Fungia* (?), *Madrepora* and *Porites arenosa*. *Orbitolites*, *Carpenteria*, *Polytrema*. *Cliona* borings. *Lithothamnion* in small nodules. Professor DAVID considers this to be "essentially coral reef rock."

(318A). Length 102 millims. Greyish-white, hard, porous where coral casts occur. About half the core of casts of *Astræa* (?), in position of growth. *Madrepora*. *Orbitolites*, *Polytrema planum*, *Amphistegina*. *Lithothamnion*. Casts of gastropods.

(319A) [590]. Length 266 millims. Whitish, with grey areas, which are mostly crystalline and

compact, whilst the whitish are porous. Some hollows, in part containing the solid casts of *Cliona* and other parasitic borings in corals, the structure of which has been dissolved away. Core mainly of corals; *Pocillopora*, *Goniastræa*, *Madrepora*, and *Porites arenosa*. Corals frequently overgrown with *Polytrema planum*. *Orbitolites*, *Carpenteria*, *Gypsina*, *Nonionina*, *Amphistegina*. Casts of gastropods and lamellibranchs. Branching and nodular *Lithothamnion*.

(320A). Length 88 millims. Rock like preceding. Mainly of coral casts; *Madrepora* and *Porites*. Foraminifera, as in the core above. Echinid spines.

(321A) [591, 592, 771]. Length 183 millims. Greyish-white, hard, except in some white patches where the rock is partly decayed, generally porous. Mainly of casts of corals; these are sometimes porous and hollow, sometimes filled up with crystalline dolomite. *Pocillopora*, *Cœloria* (?), *Cycloseris*, *Madrepora* and *Porites arenosa*. Fine detrital sediment, with numerous *Orbitolites* and other foraminifera, as in 319A, with the addition of *Planorbulina*, *Calcarina*, and *Heterostegina*, which have replaced *Gypsina* and *Nonionina*. *Lithothamnion*.

(322A, 323A). Total length 231 millims. Rock similar to preceding. Casts of branching *Pocillopora*, *Goniastræa* (?), and other corals not determinable. Corals in part replaced by crystalline dolomite; some are hollow, and enclosed by thick layers of *Polytrema planum*. *Orbitolites*, *Amphistegina*. Casts of gastropods. Fragments of *Lithothamnion*.

(324A, 325A). Total length 197 millims. Grey and white rock, hard, compact to porous, with large hollows. Only faint casts of corals. The white portions of the core mainly detrital, with *Orbitolites*, *Polytrema*, and *Amphistegina*. Fragments of *Lithothamnion*.

Depth from Surface, 890–899 *feet; Distance Bored*, 9 *feet; Total Length of Core Obtained*, 8 *feet* 5 *inches; Numbers of Cores*, 326A–340A.

Solid cylindrical cores of whitish-grey, grey, occasionally mottled, and banded dolomitic limestone. The rock is hard, partly porous, partly compact, and with some hollows where corals and gastropods have been dissolved away. The banded crystalline dolomite lines some of the cavities, and it solidly replaces many of the corals. Corals are generally distributed in these cores; in some they form the larger part of the rock, in others the larger proportion consists of foraminifera and fragmental materials. The corals are in very poor preservation, and in most only faint traces are discernible. They belong to *Pocillopora*, *Cœloria*, *Astræa*, *Madrepora*, *Porites*, and *Astræopora*. *Porites* is very abundant in some cores. Detached spicules of alcyonarians and one large specimen of *Lobophytum* are present. *Polytrema planum* and *Lithothamnion* are strongly represented. *Orbitolites*, *Textularia*, *Calcarina*, *Gypsina*, *Amphistegina*, and *Heterostegina* are present in the consolidated detrital materials, together with echinid spines, polyzoa, casts of gastropods, and stellates of *Leptoclinum*. Infilled borings of *Cliona* and other organisms retain their position in the hollows from which the corals have been removed. Professor DAVID considers that these cores are essentially a coral reef rock, such as would probably have formed in shallow water.

DETAILS.

(326A). Length 116 millims. Greyish-white, hard, compact to porous, with occasional cavities. Principally of small corals, now replaced by crystalline dolomite. *Cœloria*, *Madrepora*, and others not determinable. *Orbitolites*, polyzoon. Fragments of *Lithothamnion*. Borings of *Cliona*.

(327A). Length 118 millims. Greyish-white, hard, cavernous, with much crystalline dolomite replacing corals. *Pocillopora*, *Astræa* (?), *Porites*. *Polytrema planum*. Casts of gastropods. *Lithothamnion*.

(328A). Length 331 millims. Greyish-white, hard, in upper part with numerous small pores where alcyonarian spicules and organic fragments have been removed, in the lower more compact. Occasional hollows, lined by crystalline dolomite. Casts of *Pocillopora*, *Madrepora*, *Porites*, and *Astræopora*; these corals, for the most part, are encrusted with thick layers of *Polytrema planum*. Echinid spines, casts of gastropods, and fragments of *Lithothamnion*.

(329A) [772, 773]. Length 202 millims. Greyish-white, hard, for the most part compact, with occasional hollows. Casts of *Madrepora*, *Porites*, and other small corals which are not determinable. The corals are encrusted with *Polytrema planum* and *Lithothamnion*, branching and nodular forms of this genus are also common, and well preserved. In the lower part of this core, and continued into the next, is a mass of *Lobophytum*, 173 millims. in length, and wider than the core itself (58 millims.). It is overgrown by *Polytrema*. In the consolidated detritus, now cemented by crystalline dolomite, there are *Orbitolites*, *Textularia*, *Calcarina*, *Amphistegina*, *Heterostegina*, echinid spines, detached alcyonarian spicules, *Leptoclinum* stellates, and casts of gastropods.

(330A). Length 426 millims. Mottled and banded, greyish-white, hard, mostly compact, dolomite. In upper part a portion of the *Lobophytum* mentioned above; the rest of the core consists of a mass of *Polytrema*, branching and encrusting *Lithothamnion*, and *Madrepora*, with other small perforate corals intergrown together. *Orbitolites*, *Carpenteria*, and *Amphistegina*.

(331A). Length 238 millims. Rock similar to preceding. The core almost wholly consists of perforate corals, replaced by dolomite, and *Lithothamnion*. *Madrepora contecta* and *Porites*. Some areas of detrital materials between the corals, with *Orbitolites*, *Polytrema*, and *Amphistegina*, alcyonarian spicules, and casts of gastropods.

(332A, 333A). Total length 230 millims. Whitish-grey, speckled, hard, mostly compact, with some small hollows. Differs from the preceding in the larger proportion of detrital materials and *Lithothamnion* in comparison with the corals. Only *Madrepora* recognised. *Orbitolites*, *Polytrema*, *Amphistegina*. Gastropod casts.

(334A, 335A). Total length 225 millims. Greyish-white, hard, cavernous in places. Similar to the preceding, but with the corals somewhat more numerous. *Madrepora*, *Porites*, and piece of *Lobophytum*. Corals replaced by crystalline dolomite and overgrown by *Polytrema planum* and *Lithothamnion*. Branching and nodular forms of this genus abundant. *Amphistegina*. Gastropod casts.

(336A, 337A) [774]. Total length 206 millims. Banded, whitish-grey, hard, mostly compact, with occasional hollows. Casts of *Porites* and other small perforate corals, overgrown with thick undulating layers of *Lithothamnion*. Corals very indistinct, largely replaced by crystalline dolomite. Consolidated fragmental materials with *Orbitolites*, *Textularia*, *Calcarina*, *Gypsina inhærens*, *G. discus*, *Polytrema miniaceum*, *P. planum*, *Amphistegina* and *Heterostegina*; also alcyonarian spicules, echinid spines, and branching *Lithothamnion*.

(338A, 339A). Total length 192 millims. Whitish-grey and grey, hard, mostly compact rock, with occasional cavities. The first of these cores contains casts of *Pocillopora* and *Porites* (?) with encrusting and branching *Lithothamnion* and some *Polytrema* and other foraminifera. The second core is nearly altogether a solid mass of *Porites arenosa* (?) replaced by crystalline dolomite.

(340A). Length 215 millims. Greyish-white, hard, compact to porous. About two-thirds of this core is a continuation of the same example of *Porites* as the core above, which is thus 270 millims. in length and of a greater thickness than the diameter of the core (58 millims.). The remainder of the core consists of fragmental detritus with *Polytrema*, *Amphistegina* and *Lithothamnion*, cemented by dolomite.

Depth from Surface, 899–910 *feet; Distance Bored,* 11 *feet; Total Length of Core Obtained,* 11 *feet; Numbers of Cores,* 341A–353A.

This 11 feet of the boring is represented by an equal length of solid cylindrical cores, some of which are more than 2 feet in length, and have had to be cut into shorter lengths for convenience of study. The rock is whitish to whitish-grey, occasionally mottled and speckled, hard, dolomitic limestone, for the most part compact, but with porous areas and occasional hollows. It is composed, to a considerable extent, of corals with intermediate portions of fragmental débris of organisms, with foraminifera and *Lithothamnion.* Some of the cores are almost entirely of corals, whilst in others the fragmental materials, cemented by crystalline dolomite, predominate. The corals are poorly preserved, for the most part replaced by dolomite, and with the interspaces of the same material or of fine consolidated sediment, or they have been dissolved away leaving hollows. They belong to *Astræa, Goniastræa, Galaxea, Prionastræa, Madrepora, Astræopora, Porites* and *Montipora.* Of the alcyonaria, detached spicules and *Lobophytum* are present. *Porites* is very common, and occurs in somewhat large masses. The foraminifera belong to *Orbitolites*, very common, *Calcarina, Gypsina, Polytrema, Amphistegina* and *Heterostegina.* Echinid spines, *Serpula*, casts of gastropods and lamellibranchs. *Lithothamnion*, both encrusting and branching, is very plentiful. Infilled borings of *Cliona.* Professor DAVID considers that the corals in these cores are chiefly *in situ*, and that the rock has the character of a coral reef.

DETAILS.

(341A). Length 120 millims. Greyish-white, mottled and speckled, hard, mostly compact. About half the core of *Porites arenosa*, solidly replaced by crystalline dolomite, and *Montipora*, encrusted by *Lithothamnion* and *Polytrema planum*; the other part cf finely fragmental material, with *Amphistegina*, branching *Lithothamnion*, &c.

(342A–344A) [775]. Total length 196 millims. Greyish-white, hard, mostly compact, with small hollows. About half the cores of a small form of *Astræa* and traces of perforate corals, the remaining portion detrital with *Orbitolites, Calcarina, Gypsina inhærens, G. vesicularis*, var. *discus, Polytrema planum, Amphistegina* and *Heterostegina.* Alcyonarian spicules, partly as hollow casts; encrusting and branching *Lithothamnion.*

(345A) [776]. Length 384 millims. Greyish to greyish-white, partly mottled and speckled, mainly compact, with occasional hollows. From one-half to two-thirds of the core consists of casts of corals, mostly replaced by crystalline dolomite; they belong to *Astræa* (the same form as in the preceding), *Goniastræa* (?) *Madrepora contecta, Porites arenosa* and *Montipora* (?). Also *Lobophytum* and detached alcyonarian spicules. In the fragmental part of the cores, *Orbitolites, Textularia, Calcarina, Gypsina inhærens, Polytrema miniaceum, P. planum, Amphistegina* and *Heterostegina.* Encrusting and branching *Lithothamnion. Serpula.* Casts of gastropods.

(346A). Length 808 millims. The core has been cut transversely into six pieces, which are numbered 1–6. Whitish to whitish-grey, occasionally mottled, dolomite, hard, mostly compact, with some occasional hollows. The higher two-thirds of the rock, or about 530 millims., mainly consist of consolidated detrital materials with foraminifera and encrusting and branching *Lithothamnion*, together with some obscure perforate corals of small size. The lower part of the core contains casts of *Astræa, Prionastræa,*

Porites and *Astræopora* (?) with a considerable admixture of detrital material as well. The foraminifera, recognised with a lens, belong to *Orbitolites*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Casts of lamellibranchs.

(347A). Length 318 millims. Whitish-grey, hard, partly porous, partly compact rock, with small hollows. About one-third of the core consists of corals belonging to *Galaxea*, cf. *G. Lamarcki*,* EDWARDS and HAIME, and *Porites arenosa*, partly enclosed by *Polytrema planum*. The greater portion of the core of minute fragmental *débris*, with *Orbitolites*, *Carpenteria* and *Amphistegina*. Casts of lamellibranchs. *Lithothamnion* abundant.

(348A, 349A). Total length 263 millims. Whitish-grey to grey, partly compact, partly porous, with occasional hollows. Mainly of coral casts solidly replaced by crystalline dolomite and overgrown by *Polytrema* and *Lithothamnion*. With the exception of an example of *Pocillopora* and one of *Madrepora*, the corals belong to *Porites arenosa*. In the detrital materials alcyonarian spicules and *Orbitolites*. A group of infilled borings of *Cliona*.

(350A). Total length 481 millims. The cylindrical core is divided into four pieces. Greyish to greyish-white similar to the preceding. About two-thirds of the core consist of corals, *Madrepora* and *Porites arenosa*; of the latter one specimen apparently in position of growth is about 180 millims. in length and wider than the core (57 millims.); it is now solidly infilled with crystalline dolomite. Also a specimen of *Lobophytum*, 90 millims. long and in one part exceeding the core in width. In the detrital portion of the core *Orbitolites*, *Polytrema*, and *Amphistegina*. *Lithothamnion*, both encrusting and branching. Casts of lamellibranchs. *Cliona* borings.

(351A). Length 143 millims. Greyish, spotted white in places, hard, mostly compact. The lower half of the core consists of *Porites arenosa* (?), the upper of detrital fragments, containing numerous branching pieces and encrusting layers of *Lithothamnion* with some *Orbitolites* and *Polytrema*.

(352A) [777]. Length 611 millims. The core is divided into four pieces. Greyish, with white areas, hard, for the most part compact, with only occasional small hollows. In the upper part of the core, casts, now infilled with dolomite, of *Astræa* (the same as in core 270A, 863 feet), *Madrepora*, and *Porites*. The spaces between the corals and the lower third of the core consist of detrital fragments with alcyonarian spicules, *Orbitolites*, *Polytrema miniaceum*, *P. planum*, *Heterostegina*, echinid spines, *Leptoclinum* stellates, and *Lithothamnion*, firmly cemented together by crystalline dolomite.

(353A). Length 109 millims. Greyish, hard, mostly compact, with small cavities. In lower part of core a specimen of *Galaxea* similar to that in core No. 347A. Core mainly of minute detrital materials with some obscure corals. Alcyonarian spicules, *Polytrema planum*, and *Lithothamnion*.

Depth from Surface, 910–922 *feet; Distance Bored*, 12 *feet; Total Length of Core Obtained*, 11 *feet* 4 *inches; Numbers of Cores*, 354A–376A.

Solid cylindrical cores of grey, mottled with white, hard, mostly compact, dolomitic limestone in the upper half of the boring, whilst the same kind of rock in the lower half is whitish or cream-tinted, and in places efflorescent. Corals are present throughout, they are in the same imperfect state of preservation as noted above. Some of the cores are principally composed of corals, whilst in others only one or two are present, and the main portion of these cores consists of foraminifera and minute organic fragments, now cemented by crystalline dolomite. The predominant coral is *Porites arenosa* and forms of *Astræa*, *Orbicella*, and *Madrepora* (including *M. contecta*)

* 'Hist. Nat. Corall.,' vol. 2, p. 225.

are of common occurrence. The other genera recognised are *Pocillopora*, *Cœloria*, and *Montipora*. *Lobophytum* and detached alcyonarian spicules likewise occur. The foraminifera present belong to *Orbitolites*, *Planorbulina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. The detrital materials also include echinid spines, *Serpula*-tubes, *Leptoclinum* stellate spicules, and *Lithothamnion*.

Details.

(354A–356A). Total length 304 millims. Mottled greyish, hard, mostly compact dolomite, with a few small hollows. The upper two-thirds of the cores are principally of fragmental materials, the lower third consists largely of *Porites arenosa* apparently in position of growth. The same species also occurs in the upper cores. Casts of *Madrepora* and *Montipora* are likewise present. The corals are enclosed by layers of *Polytrema planum*. Alcyonarian spicules, *Serpula*. Casts of gastropods. Branching *Lithothamnion*.

(357A). Length 530 millims. Greyish, mottled in places, hard, with some small hollows. About two-thirds of this core consists of casts of *Porites arenosa*, now for the most part solidly infilled with crystalline dolomite and partly encrusted with *Polytrema planum*. There are also small casts of *Astræa*, *Madrepora*, and *Montipora*. The *Porites* is apparently in position of growth. *Amphistegina*. *Serpula*-tubes. Branching *Lithothamnion*. Cast of lamellibranch.

(358A). Length 92 millims. This core is merely an outer shell of rock, similar to the preceding one, with a large hollow originally occupied by *Porites arenosa*; the outer part of the coral is now infilled with crystalline dolomite and overgrown by *Polytrema*.

(359A). Length 202 millims. Greyish, mottled, and speckled with white (*Lithothamnion* mostly), hard, with small cavities. *Astræa*, *Madrepora contecta*, *Porites*, *Montipora* (?) overgrown with *Polytrema* and *Lithothamnion*. Alcyonarian spicules. Cast of large gastropod.

(360A, 361A) [778]. Total length 242 millims. Greyish, mottled, hard, partly porous, partly compact; in places cavernous where coral has been partly removed. Mainly of corals. A large cast of *Orbicella*, cf. *O. Funafutensis*, Gardiner.* *Porites arenosa* and other forms not determinable. Corals encrusted by *Polytrema* and *Lithothamnion*. *Heterostegina*.

(362A). Length 437 millims. Whitish-grey, hard, compact to porous, small hollows in places. Small casts of corals, indistinct, only *Madrepora* and *Montipora* recognised. *Lobophytum*. Greater part of core consists of consolidated minute fragmental materials with *Orbitolites*, *Carpenteria* (casts), *Polytrema*, and *Amphistegina*. Casts of gastropods. Nodular *Lithothamnion*.

•(363A, 364A) [779, 780]. Total length 150 millims. Greyish-white, hard, porous in places, cavernous. *Pocillopora*, *Madrepora*, and *Porites arenosa*. Larger part of core of consolidated detrital materials with *Orbitolites*, *Planorbulina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*, also alcyonarian spicules, *Serpula*-tubes, echinid spines, and fragments of *Lithothamnion*.

(365A). Length 167 millims. Whitish-grey, hard, porous to compact, cavernous in places where corals have been removed. Core mainly of corals; *Pocillopora* and *Porites arenosa*, a specimen nearly 100 millims. in length, and wider than the core (57 millims.), is shown in position of growth. In the fragmental materials, *Carpenteria*, *Polytrema*, echinid spines and *Lithothamnion*.

(366A, 367A). Total length 274 millims. Whitish-grey, hard, porous, with occasional cavities, efflorescent in places. Mainly of casts of corals; *Pocillopora*, *Orbicella Funafutensis* (?), *Cœloria*, Mad[illegible] and *Porites arenosa*. The corals mostly overgrown with *Polytrema* and *Lithothamnion*, *Orbitolites*, Carp[illegible] *Amphistegina*. Casts of large gastropods. *Cliona* borings in cavities from which the corals have [illegible] removed.

(368A, 369A). Total length 199 millims. Rock like preceding. Mainly of corals and Lith[illegible]

* 'Proc. Zool. Soc.,' 1899, p. 756.

Casts of *Pocillopora*, *Astræa*, *Porites arenosa*, and other small corals not determinable. *Orbitolites*, *Carpenteria*, *Polytrema*. Echinid spines, gastropod casts.

(370A). Length 121 millims. Whitish, hard, partly porous, with large hollows where gastropods have been dissolved out. A few small coral casts, including *Madrepora*; the core is principally of detrital materials with the same foraminifera as in the preceding, and a considerable amount of branching *Lithothamnion*.

(371A, 372A) [781]. Total length 170 millims. Greyish-white, speckled, hard, mostly compact, with some large hollows. Casts of small examples of *Madrepora* and *Porites*. The detrital portion of the cores contains *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema* and *Heterostegina*. Echinid spines, alcyonarian spicules, *Leptoclinum* stellates, and *Lithothamnion*. *Cliona* borings.

(373A) [593, 594]. Length 116 millims. Greyish-white, hard, compact, with porous areas. Mainly of corals; casts of *Cœloria*, *Hydnophora*, *Orbicella*, *Madrepora contecta* (?) and *Montipora* (?). *Lobophytum*. Corals overgrown by *Lithothamnion*. *Orbitolites*, *Calcarina*, *Gypsina*, *Heterostegina* and *Amphistegina*. Echinid spines.

(374A–376A) [782]. Total length 259 millims. Grey to greyish-white, hard, in part compact, in part porous, with occasional hollows. A single specimen of *Porites arenosa* extends nearly the entire length of these cores; it is apparently in the position of growth, and is now solidly infilled with crystalline dolomite. Besides the *Porites*, there are casts of *Madrepora* and *Montipora*, alcyonarian spicules, *Orbitolites*, *Polytrema*, *Amphistegina*. Echinid spines, *Lithothamnion*. Casts of gastropods. Infilled *Cliona* borings.

Depth from Surface, 922–936 *feet; Distance Bored*, 14 *feet; Total Length of Core Obtained*, 13 *feet* 9 *inches; Numbers of Cores*, 377A–404A.

Solid cylindrical cores of whitish, grey, and greyish-white, hard, dolomitic limestone. In part compact, in part porous, with occasional hollows, where corals and molluscan shells have been removed. Corals are of general occurrence throughout, but in the lower cores they are of small dimensions, and the rock chiefly consists of minute organic detrital materials with foraminifera and a large amount of branching *Lithothamnion*. The corals include *Pocillopora*, *Astræa*, and other Astræan corals, *Madrepora*, *Porites*, very abundant, and *Montipora*. Also *Millepora*, *Lobophytum*, and detached alcyonarian spicules. The foraminifera belong to *Miliolina*, *Orbitolites*, *Haddonia*, *Textularia*, *Globigerina*, *Planorbulina*, *Carpenteria*, *Polytrema*, *Amphistegina* and *Heterostegina*. There are also in the detrital materials echinid spines, *Serpula*-tubes, *Leptoclinum* stellates, casts of gastropods and lamellibranchs, and *Halimeda* (rare). *Cliona* borings.

DETAILS.

(377A–379A) [783]. Total length 255 millims. Greyish-white, hard, dense rock, with occasional small hollows lined by mammillated deposit. Largely of corals, now for the most part solidly infilled and replaced with crystalline dolomite. *Orbicella*, *Madrepora*, *Porites arenosa*, and *Montipora* (?). In the detrital material, *Miliolina*, *Carpenteria*, *Gypsina inhærens*, *Gypsina*, sp., *Polytrema planum*, *Amphistegina* and *Heterostegina*. *Serpula*-tubes.

(380A, 381A). Total length 115 millims. Rock like preceding, with casts of *Madrepora*, overgrown by *Polytrema planum* and *Lithothamnion*. *Orbitolites*, *Amphistegina* and *Heterostegina*.

(382A). Length 221 millims. Greyish-white, porous to compact, with but few hollows. More than

one-third the core of *Porites arenosa* and another perforate coral, infilled with crystalline material. Corals overgrown, as usual, with *Polytrema* and *Lithothamnion*. *Orbitolites* and *Heterostegina*.

(383A). Length 80 millims. Whitish-grey, mostly compact, dense. Casts of *Pocillopora* with *Polytrema* and *Lithothamnion*. *Carpenteria*.

(384A, 385A). Total length 255 millims. Grey with greyish-white areas, compact to porous, with occasional hollows. About two-thirds the core of *Porites arenosa*, replaced by crystalline dolomite. The corals in position of growth. Intermediate detrital areas with a large amount of branching *Lithothamnion*. *Polytrema planum*.

(386A, 387A). Total length 233 millims. Rock similar in character to preceding. Mainly of *Porites arenosa* and branching *Lithothamnion*. *Polytrema planum* and *Amphistegina*.

(388A, 389A) [784]. Total length 342 millims. Whitish-grey, hard, partly porous, partly compact, with small hollows. With the exception of a few small casts of corals, the cores almost entirely consist of fine consolidated organic sediment, now cemented by crystalline dolomite, with numerous foraminifera and a large amount of branching *Lithothamnion* in good preservation. Alcyonarian spicules. The foraminifera belong to *Miliolina*, *Orbitolites*, *Haddonia*, *Gypsina inhærens*, *Polytrema miniaceum*, *P. planum*, *Amphistegina* and *Heterostegina*. *Halimeda* (rare).

(390A). Length 168 millims. Greyish-white, dense rock, with some hollows where corals have been removed. Cast of an Astræan coral which occupies about one-third the core, the remaining portion fragmental, like the preceding, but the *Lithothamnion* is less prominent. Coral encrusted by *Polytrema planum*. Alcyonarian spicules abundant.

(391A). Length 160 millims. Greyish-white, mostly compact, with small hollows. Astræan coral, cast of *Madrepora*. Portion of stem of *Lobophytum*, about 90 millims. in length by 20 millims. in width, the spicules in close juxta-position without definite arrangement; some are solid, others empty casts. Larger part of the core of detrital materials, with much branching *Lithothamnion*. *Amphistegina*.

(392A, 393A). Total length 264 millims. Greyish-white, hard, porous to compact, cavernous in places, where corals have been removed. Greater part of core consists of corals, mostly replaced by crystalline dolomite, the remaining portion detrital, with much branching *Lithothamnion*. The corals belong to *Astræa lobata*, ELLIS and SOLANDER, and *Porites arenosa*; they appear to be in the position of growth.

(394A, 395A). Total length 312 millims. Greyish, with white spots, hard, mostly compact, with a few hollows. Small casts of *Astræa lobata*, *Madrepora*, and *Porites arenosa*. The greater part of the cores consists of detrital materials, with branching *Lithothamnion* (numerous), and alcyonarian spicules. *Amphistegina*. Cast of gastropod.

(396A). Length 158 millims. Whitish to cream-coloured, moderately hard, porous. It contains small casts of *Pocillopora* and *Madrepora*; the greater part of the core is of detrital materials, with *Orbitolites*, *Textularia*, *Polytrema planum*, alcyonarian spicules, *Lithothamnion*, and casts of gastropods.

(397A). Length 235 millims. Whitish to cream-coloured, porous, cavernous in places. Larger part of corals. Casts of *Astræa* and *Porites arenosa*, encrusted by *Polytrema planum* and *Lithothamnion*. Detrital materials, with *Orbitolites*, *Amphistegina*, and alcyonarian spicules. *Cliona* borings.

(398A, 399A) [595]. Total length 440 millims. Whitish to cream-coloured, hard, minutely porous, where small organisms have been dissolved. Casts of small examples of *Pocillopora*, *Madrepora*, *Porites*, *Montipora* (?), and *Millepora*, now for the most part replaced by crystalline dolomite. Greater part of cores of detrital materials, as in the preceding, with the addition of *Haddonia*, *Globigerina*, *Carpenteria*, *Planorbulina*, and *Heterostegina*. *Leptoclinum* stellates. Casts of lamellibranchs. Echinid spines.

(400A, 401A) [785]. Total length 471 millims. Whitish, moderately hard, very porous. Small casts of *Pocillopora* and *Millepora*. Cores nearly altogether of minute fragmental materials, with *Orbitolites*, *Textularia*, *Carpenteria*, *Gypsina*, *Polytrema miniaceum*, *P. planum*, alcyonarian spicules, echinid spines, and plates, and also with numerous fragments of *Lithothamnion*, which are cemented by crystalline dolomite.

(402A, 403A). Total length 233 millims. Rock whitish, moderately hard, porous, like the preceding.

Casts of *Pocillopora*, *Montipora* (?), and *Millepora* common. Cores mainly of fragmental materials, with *Orbitolites*, *Polytrema*, *Amphistegina*, echinid spines, and much branching *Lithothamnion*. *Cliona* borings.

(404A). Length 204 millims. Rock grey, with very numerous, irregular patches of white, which are branching and nodular fragments of *Lithothamnion*. Hard, mostly compact. Small casts of *Pocillopora* and *Millepora*. Mainly of detrital materials. *Polytrema*, *Amphistegina*. Casts of gastropods.

Depth from Surface, 936–945 *feet; Distance Bored*, 9 *feet; Total Length of Core Obtained*, 8 *feet* 4 *inches; Numbers of Cores*, 405A–421A.

Solid cylindrical cores of greyish-white, hard, for the most part, compact to porous, dolomitic limestone, with occasional cavities. Corals are distributed throughout the rock, but not uniformly; some cores are nearly altogether composed of them, while in others only a few small casts are present, and the rock is mainly of fragmental materials, with *Polytrema* and other foraminifera, and branching and encrusting *Lithothamnion*. The most abundant corals belong to *Pocillopora*, *Cœloria*, *Madrepora*, and *Porites*, whilst *Seriatopora*, *Astræa*, and *Prionastræa* are less numerously represented. Small forms of *Millepora* occur, as in the preceding cores. Alcyonarian spicules. The foraminifera include *Orbitolites*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Echinid spines, *Serpula*-tubes, casts of gastropods, and *Cliona* borings.

DETAILS.

(405A, 406A) [786]. Total length 256 millims. Greyish groundmass, filled with numerous white fragments, chiefly of branching *Lithothamnion*. A few casts of *Pocillopora*, a simple Astræan, and *Millepora*. Corals encrusted by *Polytrema planum* and *Lithothamnion*. Alcyonarian spicules. *Gypsina*, *Amphistegina*, *Heterostegina*. Echinid spines.

(407A). Total length 453 millims. Greyish-white, hard, porous, with compact areas where corals have been infilled with crystalline dolomite; occasional small hollows. Casts of *Pocillopora*, *Cœloria*, simple Astræan, branching *Madrepora*, *Porites arenosa*, and *Millepora*. The core is largely of detrital materials, with *Orbitolites*, *Carpenteria*, *Polytrema*, *Amphistegina* (very numerous), echinid spines, and *Lithothamnion*. *Cliona* borings.

(408A). Length 153 millims. Greyish-white, hard, porous, with a few small hollows. About one-half the core of casts of corals. *Pocillopora*, *Seriatopora*, small Astræan, *Orbicella*, branching *Madrepora*, and *Porites*; the corals are often encrusted by *Polytrema planum*. *Orbitolites*, *Amphistegina* very common. *Serpula*-tubes.

(409A). Length 256 millims. Rock greyish-white, hard and porous, like preceding. Casts of *Pocillopora*, *Madrepora*, and *Porites*; the structure has been either dissolved away, or replaced by crystalline dolomite. Foraminifera as in No. 408A.

(410A, 411A). Total length 240 millims. Greyish-white, hard, compact to porous, with occasional hollows. Casts of *Pocillopora*, simple Astræan, *Madrepora*, and *Porites arenosa*. *Orbitolites*, *Polytrema*, *Amphistegina*. Casts of gastropods. *Lithothamnion*.

(412A). Length 120 millims. Whitish, with some grey areas. The white portions softer than the grey, and occasionally efflorescent. Casts of *Pocillopora*, and *Prionastræa* (?). Detrital materials, with *Orbitolites*, *Carpenteria*, *Amphistegina*. *Lithothamnion*.

(413A, 414A) [787]. Total length 228 millims. Whitish-grey, hard, partly porous, partly compact,

where corals have been solidly replaced by crystalline dolomite. Cores principally of coral casts. *Cœloria*, branching *Madrepora*, and *Porites arenosa*. Foraminifera, as in preceding. Casts of gastropods.

(415A, 416A). Total length 345 millims. Rock similar to preceding; mainly composed of corals. Casts of *Cœloria* (in position of growth), *Astræa lobata*, LAM., *Madrepora contecta*, and *Porites arenosa*. The corals overgrown by layers of *Polytrema planum* and *Lithothamnion*. In detrital material, *Orbitolites*, *Carpenteria*, and *Amphistegina*.

(417A) [788]. Length 97 millims. Greyish-white, hard, porous. The core almost wholly formed of two species of corals fairly well shown. The structure is for the most part replaced by crystalline dolomite, while the interstices are in part lined by rhombohedral crystals, in part empty. *Prionastræa*, cf. *P. magnifica*,* BLAINV., and *Astræa* sp., *Polytrema planum*, and *Amphistegina*.

(418A–420A). Total length 243 millims. Whitish-grey, hard, porous to compact, with small hollows. Cores mainly of corals, often solidly replaced by crystalline dolomite. *Astræa lobata*, *Madrepora contecta*, *Porites arenosa*, and *Astræopora*. Alcyonarian spicules. Detrital materials with *Orbitolites*, *Carpenteria*, and *Amphistegina*. Branching *Lithothamnion*. Casts of gastropods.

(421A). Length 110 millims. Greyish (compact) and whitish (porous). Core almost entirely of *Porites arenosa* with a fringe of consolidated detrital materials containing *Orbitolites* and *Amphistegina*.

Depth from Surface, 945–957 *feet; Distance Bored*, 12 *feet; Total Length of Core Obtained*, 10 *feet* 11 *inches; Numbers of Cores*, 422A–442A.

This part of the boring consists of nearly continuous, solid, cylindrical cores of whitish to greyish-white dolomitic limestone. The rock is hard (H = 4), partly porous, partly compact, in some portions it is whitish and less coherent. The cores to a large extent are composed of corals, some replaced and filled up solid with crystalline dolomite, and in part with fine sediment, in others the structure has been dissolved away, and the space is empty or merely lined with crystals. The corals in many instances appear to be in the position of growth. They belong to the following genera: *Pocillopora* common; *Cœloria* common; *Goniastræa*, *Astræa* frequent; *Galaxea*, *Prionastræa*, both common; *Madrepora*, *Montipora*, *Porites* very common; and *Astræopora*. Also *Millepora*, *Lobophytum*, and detached alcyonarian spicules. The spaces between the corals are filled in with fine consolidated detrital materials containing *Orbitolites*, *Globigerina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Casts of gastropods, echinid spines. *Lithothamnion*. *Cliona* borings.

DETAILS.

(422A, 423A). Total length 265 millims. Whitish, with thick grey bands, hard, partly compact, partly porous. Corals numerous. *Prionastræa magnifica*, *Madrepora*, *Montipora*, and *Porites arenosa*. In the detrital materials *Orbitolites*, *Carpenteria*, *Amphistegina*, *Lithothamnion*.

(424A) [789]. Length 327 millims. Whitish rock, in places speckled, occasionally soft so that it scratches readily with a knife, porous. Casts of *Madrepora* and *Astræopora*. Alcyonarian spicules. The larger part of the core is a fine detrital sediment containing *Orbitolites*, *Carpenteria*, *Calcarina defrancii*, *Polytrema*, *Gypsina inhærens*, *Amphistegina*, and *Heterostegina*. Echinid plates. Fragments of *Lithothamnion*. Casts of gastropods and lamellibranchs.

* 'Zooph. Dict. Sci. Nat.,' vol. 60, p. 340, 1830; also 'Man. Act' Plate 54, fig. 3, 1834.

(425A) [790]. Length 333 millims., width of cylinder 58 millims. Whitish-grey, hard, compact to porous, with occasional small hollows. The upper half of the core mainly of corals, the lower of foraminifera and detrital materials. *Galaxea* (?), *Porites arenosa*, *Astræopora*; also *Millepora*. The foraminifera belong to *Orbitolites* (very common), *Globigerina bulloides*, *Carpenteria*, *Polytrema planum*, *Amphistegina*, and *Heterostegina*. *Serpula*-tubes. Cast of turretted gastropod. Branching *Lithothamnion*.

(426A). Length 234 millims. Whitish-grey, hard, porous, except where corals have been infilled with crystalline dolomite. Mainly of coral casts, *Galaxea Ellisi* (?), *Porites arenosa*, *Montipora*, and *Madrepora* (?), *Lobophytum* growing on *Porites*, and detached spicules of alcyonaria. Corals in position of growth; encrusted with *Polytrema planum* and *Lithothamnion*. *Orbitolites* and *Amphistegina*.

(427A) [791]. Length 331 millims. Whitish-grey, hard, porous to compact. Core mainly of corals. *Galaxea Ellisi* (?) growing in large masses, apparently in position of growth, also *Astræa* (?). Alcyonarian spicules very numerous. Corals overgrown with *Polytrema* and *Lithothamnion*. Detrital materials with *Orbitolites*, *Globigerina bulloides*, *Carpenteria*, *Calcarina*, *Gypsina*, and *Amphistegina*.

(428A, 429A). Total length 182 millims. Whitish-grey, hard, with some hollows. Largely of corals. *Astræa lobata*, *Cœloria*, *Porites arenosa*. Alcyonarian spicules, echinid spines. Foraminifera as in preceding.

(430A). Length 160 millims. Whitish-grey, hard, porous. Almost wholly of corals apparently in position of growth. *Cœloria*, *Astræa lobata*, *Prionastræa magnifica*, and *Madrepora*. Alcyonarian spicules. *Orbitolites*, *Polytrema planum*, *Amphistegina*. *Lithothamnion*.

(431A–433A). Total length 334 millims. Greyish-white, hard, porous, with occasional cavities. Largely of casts of corals. *Pocillopora*, *Astræa lobata*, *Prionastræa magnifica* (?), *Madrepora* and *Porites*. *Millepora*, *Lobophytum*, alcyonarian spicules. Foraminifera as in preceding. Casts of gastropods. Echinid spines. *Lithothamnion*.

(434A, 435A). Total length 211 millims. Whitish-grey, hard, porous, with some compact areas. Mainly of corals. *Pocillopora*, *Cœloria*, *Madrepora*, and *Porites arenosa*. *Amphistegina*, *Lithothamnion*.

(436A). Length 121 millims. Whitish-grey, hard, mostly compact. *Prionastræa magnifica* and branching *Madrepora*. Alcyonarian spicules. Core largely of detrital materials with *Orbitolites*, *Carpenteria*, *Amphistegina*, echinid spines. Casts of gastropods. Branching *Lithothamnion* numerous. Casts of unusually large *Cliona* borings.

(437A). Length 198 millims. Greyish-white, hard, porous, with hollows where corals have been removed. Somewhat more than half the core of corals. *Pocillopora*, *Cœloria*, *Madrepora*, cast of large *Porites* solidly infilled with crystalline dolomite. In detrital portion of core the same kinds of organisms as in the core above. Casts of lamellibranchs.

(438A). Length 218 millims. Whitish-grey, hard, porous, dolomite, with occasional hollows. Numerous small casts of corals. *Pocillopora*, Astræan, *Madrepora* and *Porites*. Nodular lumps of *Millepora*. Corals in position of growth. *Orbitolites*, *Carpenteria*, *Amphistegina*, *Heterostegina*. Echinid spines. Branching *Lithothamnion* abundant.

(439A–441A). Total length 267 millims. Rock similar to preceding. Numerous casts of small corals, intermediate areas of finely detrital fragments with foraminifera. *Pocillopora* abundant, *Cœloria*, Astræan, *Madrepora*, and *Porites*. Alcyonarian spicules. *Orbitolites*, *Carpenteria*. Casts of gastropods. Branching *Lithothamnion*.

(442A). Length 102 millims. Greyish-white, hard, porous, with some hollow spaces. Casts of corals and detrital materials. *Pocillopora*, *Goniastræa solida*,* Bl., small Fungid and *Madrepora*. *Orbitolites*, *Amphistegina*, numerous. *Lithothamnion*.

---

* 'Dict. Sci. Nat.,' vol. 60, p. 338, 1830.

[illegible]

[illegible]

[illegible] Alcyonarian [illegible] spines. [illegible]

(445A). [illegible] consisting [illegible]

(446A). [illegible] Larger corals [illegible] and an undetermined Fungid [illegible] in the lower [illegible] and Heterologia. [illegible]

(446A–448A). [illegible] partly porous, with large hollows where [illegible]. Casts of [illegible], in large masses [illegible] and the interstices [illegible] Alcyonarian spicules [illegible] fragments, together with *Orbitolites*, *Carpenteria*, [illegible] Echinid spines. Casts of gastropods and lamellibranchs. [illegible]

(449A). Length 11½ inches. [illegible] hard, porous, with small hollows. Casts of [illegible], *Orbicella*, *Madrepora*, and *Porites* [illegible]. Casts of *Carpenteria* and *Amphistegina*.

Depth from Surface, 963–973 feet ; Distance Bored, 10 feet ; Total Length of Core Obtained, 9 feet 7 inches ; Numbers of Cores, 450A–470A.

Cylindrical cores of whitish and whitish-grey dolomitic limestone, hard, partly compact, partly porous, with small hollows, and occasionally large cavities, where corals have been removed. Like the preceding, these cores also consist, to a large

extent, of corals, now either solidly replaced by crystalline dolomite or with the structure dissolved away, and the interstices are lined with crystals or infilled with consolidated sediment. The following genera are represented : *Pocillopora*, common ; *Seriatopora*, rare ; *Cœloria*, *Astræa*, and other undetermined Astræans ; *Fungia*, *Madrepora*, common ; *Montipora*, *Porites*, very common, and growing in large masses. *Millepora*, *Lobophytum*, alcyonarian spicules. The detrital material between the corals contains *Orbitolites*, *Placopsilina*, *Textularia*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Also echinid spines, *Serpula*-tubes, casts of gastropods and lamellibranchs (*Lithodomus*). *Lithothamnion*. *Cliona* borings. The organisms are cemented by crystalline dolomite, but frequently this material does not completely fill the interspaces.

Details.

(450A–452A). Total length 371 millims. Whitish-grey, hard, partly porous, and with small hollows. Mainly of coral casts. *Pocillopora*, *Cœloria*, *Astræa lobata*, *Montipora* (?), and *Porites arenosa*, in large masses, to 115 millims. in length, and wider than the core. They are apparently in the position of growth. The *Porites* occasionally bored by *Lithodomus*, the shell of which is still present in the boring. The detrital material contains *Orbitolites*, *Carpenteria*, *Polytrema planum*, and *Amphistegina*. Casts of lamellibranchs. *Lithothamnion*.

(453A), Length 248 millims. Whitish-grey, similar to preceding. Casts of small examples of *Madrepora* and *Porites*. Alcyonarian spicules. Larger part of the core of detrital materials, with foraminifera, as in the core above. *Serpula*-tubes. Branching *Lithothamnion*.

(454A, 455A). Total length 216 millims. Whitish, speckled, minutely porous. The upper core consists chiefly of casts of *Pocillopora* and *Porites arenosa*. Alcyonarian spicules. The lower core, mainly of fragmental materials, with *Orbitolites*, *Carpenteria*, *Amphistegina* (very abundant), and *Heterostegina*. Numerous fragments of *Lithothamnion*.

(456A, 457A) [794]. Total length 231 millims. Greyish-white, hard, porous. The upper part of the cores chiefly of coral casts. *Cœloria*, *Porites*, and a piece of *Lobophytum* 48 millims. in length, wider than the core. The lower portion of the core consists for the most part of detrital materials, with *Orbitolites*, *Textularia*, *Carpenteria*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Echinid spines and encrusting and branching *Lithothamnion*. Under the microscope some of the spicules composing the *Lobophytum* are seen to retain their brownish aspect and obscurely fibrous structure ; in others, however, the brownish outer layer either merely encloses an empty mould, or the interior is filled with crystalline dolomite.

(458A–461A). Total length 343 millims. Greyish-white, hard, mostly porous and with irregular hollows. Casts of *Pocillopora*, Astræan coral, branching *Madrepora*, and solidly replaced *Porites*, with undulating layers of *Polytrema planum* and *Lithothamnion* growing over it. Alcyonarian spicules. The larger part of the cores consists of somewhat coarse-grained fragments of organisms with *Orbitolites*, *Carpenteria*, *Amphistegina* and *Heterostegina*. Echinid spines. *Serpula*-tubes. Casts of lamellibranch shells, some with infilled *Cliona* borings.

(462A–464A). Total length 241 millims. Whitish-grey, hard, minutely porous. Casts of *Pocillopora*, *Fungia*, about 60 millims. in diameter, branching *Madrepora*. Alcyonarian spicules. The larger part of the cores of detrital materials, like the preceding, with *Orbitolites*, *Polytrema planum* and *Amphistegina*. Casts of lamellibranchs and gastropods.

(465A, 466A). Length 430 millims. Whitish-grey, hard, partly compact, partly porous dolomite. The greater part of these cores consists of specimens of *Porites arenosa*, in part solidly replaced by crystalline materials, in part minutely porous. One specimen is 325 millims., or 13 inches in height, and wider than

the core. Another specimen, evidently in position of growth, is 70 millims. in height and about the width of the core. The specimens are bored by *Lithodomus*, the borings are 14 millims. across, and mostly infilled with fine consolidated sediment. *Madrepora* is also present. In the fragmental detritus there are alcyonarian spicules, *Polytrema planum*, *Amphistegina* and echinid spines.

(467A). Length 229 millims. Rock like the preceding. Casts of *Pocillopora*, *Seriatopora*, simple Astræan, *Madrepora* and *Porites*. Amongst the detrital materials there are alcyonarian spicules, *Amphistegina*, *Heterostegina*, echinid spines and branching *Lithothamnion*. Gastropod casts.

(468A). Length 251 millims. Whitish-grey, hard, porous, with occasional hollows. *Pocillopora*, Astræan coral, genus uncertain, *Madrepora contecta*, *Porites*. *Millepora*, alcyonarian spicules. *Amphistegina*. *Lithothamnion*. Casts of gastropods. *Cliona* borings.

(469A). Length 106 millims. Grey with whitish spots in places; large cavities. Core almost entirely of *Porites arenosa*, in part solidly infilled with crystalline dolomite, in part porous or dissolved away. *Amphistegina*. Branching *Lithothamnion*.

(470A) [598]. Length 204 millims. Whitish-grey, mottled, hard, compact to porous. Core mainly of corals. *Cœloria*, *Psammocora* (?), *Madrepora*, *Porites arenosa*. Alcyonarian spicules. Detrital material with *Placopsilina*, *Orbitolites*, common, *Textularia rugosa*, *Carpenteria*, *Gypsina*, *Polytrema* and *Amphistegina*. Echinid spines. Much encrusting and branching *Lithothamnion*, showing the structure well. Casts of gastropods.

Depth from Surface, 973–983 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 8 *feet* 5 *inches; Numbers of Cores*, 471A–490A.

Solid cylindrical cores of greyish to greyish-white, hard, dolomitic limestone. The rock is partly compact and partly porous, with cavities in places where corals have been removed. Corals are distributed throughout, some cores are principally composed of them, in others they are surrounded by masses of coarse fragmental materials. The corals are as usual in the condition of casts; the structure replaced by crystalline dolomite, and the interstices infilled with consolidated sediment. They belong to *Pocillopora*, *Cœloria*, *Astræa*, *Orbicella*, *Fungia*, *Madrepora*, *Montipora*, *Porites* and *Astræopora*. Alcyonarian spicules are also present. The detrital portion of the cores contains *Orbitolites*, *Haddonia*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina* and *Heterostegina*. Echinid spines, *Leptoclinum* stellate spicules. Casts of lamellibranchs and gastropods. Encrusting and branching *Lithothamnion*. Infilled *Cliona* borings. These various organisms and organic fragments are cemented together by crystalline dolomite, which, however, often only partially fills the interspaces.

Details.

(471A). Length 270 millims. Greyish-white, for the most part minutely porous, with large hollow. Corals throughout, but about half the core of fragmental materials. *Cœloria*, *Astræa* (?), *Madrepora* and *Porites*. Corals encrusted by *Polytrema planum* and *Lithothamnion*. Alcyonarian spicules. *Amphistegina*, echinid spines, branching and fragmentary *Lithothamnion*.

(472A, 473A). Total length 229 millims. Greyish-white, compact to porous, with some hollows. Cores principally of coral casts; *Madrepora*, *Porites* and *Astræopora*. Alcyonarian spicules, *Polytrema planum*, *Lithothamnion*. Casts of large lamellibranchs.

(474A). Length 243 millims. Whitish-grey with white spots (*Lithothamnion*) minutely porous. Casts

of *Fungia* (?), *Madrepora* and *Porites*. Alcyonarian spicules. Lower half of core principally of detrital materials, containing the same forms as the preceding with the addition of *Cliona* borings.

(475A). Length 123 millims. Greyish-white, mottled and speckled. Cast of *Madrepora*, overgrown by *Polytrema planum*. Also cast of fragment of large bivalve shell; the shell has been dissolved away and the space is now occupied with infilled *Cliona* borings. Echinid spines. Fragments of *Lithothamnion*.

(476A–479A) [795]. Total length 395 millims. Greyish-white, hard, compact to porous. Casts of *Astræa*, cf. *A. lobata*, numerous. Detrital materials are more abundant than corals in the lower cores. The foraminifera include *Orbitolites*, *Haddonia*, *Carpenteria*, *Polytrema planum*, *Amphistegina* and *Heterostegina*. Echinid spines. Encrusting and branching *Lithothamnion*, abundant.

(480A). Length 163 millims. Greyish, with white areas, mostly compact. From one-third to one-half the core of *Porites arenosa* (?). Alcyonarian spicules, abundant. *Carpenteria*, *Amphistegina* and *Heterostegina*. Casts of gastropods. *Lithothamnion*.

(481A–484A) [796]. Total length 419 millims. Greyish, hard, porous. The cores consist of coarse fragmental organic materials, cemented by the crystalline dolomite, but the interspaces are not completely filled; in the cores there are many coral fragments as well as thick bands of them in position of growth. The corals comprise *Pocillopora*, *Cœloria*, *Madrepora*, and *Porites*. Alcyonarian spicules. The foraminifera belong to *Orbitolites*, *Haddonia*, *Carpenteria*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Echinid plates and spines. Numerous fragments of branching *Lithothamnion*.

(485A, 486A). Total length 144 millims. Grey, hard, mostly compact, with porous areas. Cores mainly of corals solidly replaced by crystalline dolomite. *Porites arenosa* and *Orbicella*, cf. *O. heliopora*, LAM. Some coarse detrital materials with the same organisms as in the cores above, except that *Haddonia* and *Carpenteria* were not observed.

(487A, 488A) [797]. Total length 158 millims. Greyish-brown with whitish bands, hard, mostly compact, cavernous. Cores chiefly of corals, growing in thick undulating, nearly horizontal layers; they belong to *Porites*, *Montipora*, *Astræopora*, and are partly overgrown by *Polytrema* and *Lithothamnion*. Alcyonarian spicules. In the detrital materials, *Orbitolites*, *Carpenteria*, *Gypsina*, *Amphistegina*, and *Heterostegina* are present, with echinid spines and plates and *Leptoclinum* stellates.

(489A). Length 150 millims. Greyish-white, mottled; large hollows in places where corals have been dissolved out. Thick layers of *Porites* and *Astræopora*, overgrown by the *Polytrema* and *Lithothamnion*. Larger half of core of coarse detrital material with *Orbitolites*, *Carpenteria*, and *Amphistegina*.

(490A). Length 253 millims. Upper half of core whitish-grey, with layers of *Astræopora* (?) and coarse-grained detrital material with foraminifera, the same as in the preceding; the lower half of much finer fragmental material composed of the same kinds of organisms, solidly cemented with crystalline dolomite.

Depth from Surface, 983–991 *feet; Distance Bored*, 8 *feet; Total Length of Core Obtained*, 7 *feet* 1 *inch; Numbers of Cores*, 491A–507A.

Cylindrical cores of greyish-white to greyish-brown, hard, dolomitic limestone. In the upper 2 feet the cores are almost exclusively of foraminiferal and fragmental materials of a uniform character; in the rest of the cores there are in places some casts of corals, but in the main the rock is composed of the same detrital material as in the upper portion. The corals for the most part are unfavourably preserved; they belong to *Cœloria*, simple Astræan forms, and *Madrepora contecta*. *Millepora* occurs but rarely, while alcyonarian spicules are common. The foraminifera comprise the usual forms: *Orbitolites*, *Textularia*, *Carpenteria*, *Calcarina*, *Polytrema*, *Amphistegina* and *Heterostegina*. Echinid spines, casts of lamellibranchs and gastropods are present,

and a large amount of branching and fragmentary *Lithothamnion*. The materials are cemented by crystalline dolomite.

DETAILS.

(491A–494A) [798]. Total length 503 millims. Greyish, speckled white, hard, minutely porous. With the single exception of a small perforate coral, perhaps *Madrepora*, the cores are uniformly composed of foraminifera and fragments of branching *Lithothamnion*, with alcyonarian spicules and echinid spines. The foraminifera include *Orbitolites*, common, *Textularia*, *Carpenteria*, *Calcarina*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, abundant, and *Heterostegina*, common. The interspaces between these organisms are only partially filled with crystalline dolomite.

(495A, 496A). Total length 277 millims. Greyish, speckled, hard and porous. Somewhat more than half the cores consist of coarse fragmental materials with *Orbitolites*, *Amphistegina*, and *Heterostegina*, the remainder is composed of casts of *Cœloria* and *Madrepora contecta* (?). The former is bored by *Lithodomus*. Echinid spines and branching *Lithothamnion*.

(497A). Length 442 millims. Greyish-white, hard, compact to minutely porous. Beyond casts of a few simple forms of an Astræan coral and a specimen of *Madrepora contecta* (?), the core consists of the same foraminifera and other organisms as in the preceding, with the addition of *Carpenteria* and casts of gastropods.

(498A–501A). Total length 379 millims. Greyish-brown, with whitish undulating bands, hard, cavernous. Very crystalline. The cavities in these cores were probably occupied originally by corals, and corals likewise appear to have been in the solid portions of the rock now filled in with crystalline dolomite and surrounded by encrusting layers of *Lithothamnion*. Indications of *Madrepora*. Foraminifera as in preceding. *Orbitolites* abundant, *Polytrema* and *Amphistegina*. Echinid spines.

(502A–504A) [799]. Total length 326 millims. Greyish-brown, hard, compact to porous, very crystalline rock. With the exception of two or three small casts of corals, too imperfect for determination, the cores appear to be entirely of foraminifera and fragmental *Lithothamnion*, alcyonarian spicules and echinid spines. *Orbitolites*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*, can be recognised in the microscopic section.

(505A–507A). Total length 229 millims. Mottled greyish-brown, hard, compact to porous, in places cavernous. Large amount of the banded crystalline deposit lining and filling the hollows. Imperfect casts of *Madrepora contecta*. Small *Millepora*. Encrusting *Polytrema planum* and *Lithothamnion*. *Orbitolites*, *Amphistegina*, echinid spines.

Depth from Surface, 991–1006 *feet*; *Distance Bored*, 15 *feet*; *Total Length of Core Obtained*, 12 *feet* 8 *inches*; *Numbers of Cores*, 508A–527A.

Solid cylindrical cores of greyish-white to greyish-brown, dense, hard, dolomitic limestone. Compact to porous, with occasional cavities where corals have been removed. Banded crystalline deposit lining and filling up the pores and hollows. Corals are distributed throughout the cores, but they do not occupy so much space as the foraminiferal and detrital materials. They belong to *Stylophora*, *Pocillopora*, *Seriatopora*, *Cœloria*, *Astræa*, *Orbicella*, *Cyphastræa* (?), *Prionastræa*, *Fungia*, *Madrepora*, *Montipora* (?) and *Astræopora*. *Millepora* fairly common; *Lobophytum* and detached alcyonarian spicules are also present. The foraminifera belong to *Orbitolites*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Echinid spines, *Serpula*-tubes. Casts of lamellibranchs, and encrusting and branching *Lithothamnion*.

DETAILS.

(508A, 509A). Total length 180 millims. Mottled greyish-white, compact to porous, occasional small hollows. Casts of branching *Madrepora*. Small form of *Millepora*, fragment of *Lobophytum*, and detached alcyonarian spicules. The larger part of the cores consist of detrital materials, with *Orbitolites* and *Amphistegina*, Echinid spines and many pieces of *Lithothamnion*.

(510A) [800, 801]. Length 308 millims. Speckled greyish-white, compact to porous, with many small hollows. Numerous small coral casts, *Pocillopora*, *Seriatopora*, simple Astræan, and *Madrepora*. *Millepora*. The foraminifera comprise *Orbitolites*, *Carpenteria*, *Gypsina inhaerens*, *G. globulus*, *Polytrema miniaceum*, *P. planum*, *Amphistegina* and *Heterostegina*. Alcyonarian spicules, echinid spines, the structure well shown; fragmentary *Lithothamnion*.

(511A, 512A). Total length 174 millims. Mottled greyish-brown, compact to porous, with occasional hollows. Casts of *Seriatopora*, *Fungia*, and *Madrepora*, and other small corals too obscure to be determined. *Millepora*. *Orbitolites* numerous, *Polytrema planum* encrusting corals, *Amphistegina*. Echinid spines, casts of lamellibranchs. *Lithothamnion*.

(513A, 514A). Total length 227 millims. Rock like the preceding; cavernous in places where corals have been removed. Casts of *Seriatopora*, *Astræa*, *Fungia* and *Madrepora* (?) encrusted by *Polytrema planum*. The detrital materials contain *Orbitolites*, *Amphistegina*, echinid spines and *Lithothamnion*.

(515A) [802]. Length 403 millims. Greyish-brown, hard, partly compact, partly porous, dolomitic limestone. The upper third of the core consists principally of corals: *Seriatopora*, *Astræa*, and *Montipora* (?); the rest of the core, with the exception of casts of *Seriatopora*, is composed of detrital materials and foraminifera: *Orbitolites*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Alcyonarian spicules, echinid spines, encrusting and branching *Lithothamnion*.

(516A, 517A). Length 227 millims. Rock like the preceding one. The upper core contains numerous slender branches of *Seriatopora*, encrusted by *Polytrema planum*. In the lower core besides *Seriatopora*, there is a cast of a small *Astræa*. In the detrital materials, the only organisms which can be recognised with a lens are *Orbitolites*, *Amphistegina*, echinid spines and *Lithothamnion*.

(518A). Length 232 millims. Greyish-white, mottled, hard, compact to porous. Largely of corals, including *Seriatopora*, *Cœloria*, *Astræa* and *Madrepora*, encrusted by *Polytrema* and *Lithothamnion*. The corals are very unfavourably preserved, being for the most part replaced by crystalline dolomite. *Orbitolites* and *Amphistegina*.

(519A, 520A) [599, 803]. Total length 134 millims. Whitish-grey, minutely porous, with compact areas. Mainly of corals; *Cœloria*, *Madrepora*, *Porites*, or *Astræopora* in position of growth. Alcyonarian spicules, echinid plates. *Orbitolites*, *Amphistegina*. Encrusting *Lithothamnion*.

(521A). Length 320 millims. Grey and whitish, hard, occasionally cavernous. Corals numerous, but very indistinct. *Stylophora*, *Pocillopora*, and the same doubtful *Porites* or *Astræopora* as in the preceding core. *Amphistegina*. Large echinid spines. Branching and encrusting *Lithothamnion* common.

(522A). Length 150 millims. Greyish-brown, hard, mostly compact, dolomite. Core mainly of branching *Pocillopora* and indications of other corals as well. Branching *Lithothamnion*. No foraminifera distinguishable with a lens.

(523A). The length of the whole core is 947 millims. or about 3 feet 2 inches. It has been divided into six subequal pieces averaging 157 millims. each. The pieces are numbered 1–6.

(1–2). Greyish-brown, hard, compact to porous, with occasional small cavities. Numerous casts of branching *Pocillopora*, similar to that in the preceding core, and indications of a perforate coral, replaced and nearly obliterated by the crystalline dolomite. Cast of gastropod, echinid spines. A large quantity of branching *Lithothamnion*. Foraminifera not distinguishable with lens.

(3). Greyish-brown, dense, minutely porous, occasionally cavernous. Several areas, now infilled with crystalline dolomite, appear to have been originally corals, but nothing definite is shown beyond traces

and a large amount of branching and fragmentary *Lithothamnion*. The materials are cemented by crystalline dolomite.

DETAILS.

(491A–494A) [798]. Total length 503 millims. Greyish, speckled white, hard, minutely porous. With the single exception of a small perforate coral, perhaps *Madrepora*, the cores are uniformly composed of foraminifera and fragments of branching *Lithothamnion*, with alcyonarian spicules and echinid spines. The foraminifera include *Orbitolites*, common, *Textularia*, *Carpenteria*, *Calcarina*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, abundant, and *Heterostegina*, common. The interspaces between these organisms are only partially filled with crystalline dolomite.

(495A, 496A). Total length 277 millims. Greyish, speckled, hard and porous. Somewhat more than half the cores consist of coarse fragmental materials with *Orbitolites*, *Amphistegina*, and *Heterostegina*, the remainder is composed of casts of *Cœloria* and *Madrepora contecta* (?). The former is bored by *Lithodomus*. Echinid spines and branching *Lithothamnion*.

(497A). Length 442 millims. Greyish-white, hard, compact to minutely porous. Beyond casts of a few simple forms of an Astræan coral and a specimen of *Madrepora contecta* (?), the core consists of the same foraminifera and other organisms as in the preceding, with the addition of *Carpenteria* and casts of gastropods.

(498A–501A). Total length 379 millims. Greyish-brown, with whitish undulating bands, hard, cavernous. Very crystalline. The cavities in these cores were probably occupied originally by corals, and corals likewise appear to have been in the solid portions of the rock now filled in with crystalline dolomite and surrounded by encrusting layers of *Lithothamnion*. Indications of *Madrepora*. Foraminifera as in preceding. *Orbitolites* abundant, *Polytrema* and *Amphistegina*. Echinid spines.

(502A–504A) [799]. Total length 326 millims. Greyish-brown, hard, compact to porous, very crystalline rock. With the exception of two or three small casts of corals, too imperfect for determination, the cores appear to be entirely of foraminifera and fragmental *Lithothamnion*, alcyonarian spicules and echinid spines. *Orbitolites*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*, can be recognised in the microscopic section.

(505A–507A). Total length 229 millims. Mottled greyish-brown, hard, compact to porous, in places cavernous. Large amount of the banded crystalline deposit lining and filling the hollows. Imperfect casts of *Madrepora contecta*. Small *Millepora*. Encrusting *Polytrema planum* and *Lithothamnion*. *Orbitolites*, *Amphistegina*, echinid spines.

Depth from Surface, 991–1006 *feet; Distance Bored*, 15 *feet; Total Length of Core Obtained*, 12 *feet* 8 *inches; Numbers of Cores*, 508A–527A.

Solid cylindrical cores of greyish-white to greyish-brown, dense, hard, dolomitic limestone. Compact to porous, with occasional cavities where corals have been removed. Banded crystalline deposit lining and filling up the pores and hollows. Corals are distributed throughout the cores, but they do not occupy so much space as the foraminiferal and detrital materials. They belong to *Stylophora*, *Pocillopora*, *Seriatopora*, *Cœloria*, *Astræa*, *Orbicella*, *Cyphastræa* (?), *Prionastræa*, *Fungia*, *Madrepora*, *Montipora* (?) and *Astræopora*. *Millepora* fairly common; *Lobophytum* and detached alcyonarian spicules are also present. The foraminifera belong to *Orbitolites*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Echinid spines, *Serpula*-tubes. Casts of lamellibranchs, and encrusting and branching *Lithothamnion*.

Heterostegina. Echinid spines, *Serpula*, and nodular *Lithothamnion*. The small organisms and fragments are coated by numerous, thin successive layers of crystalline dolomite which cements them together.

(535A). Length 425 millims. Greyish-brown, very hard and dense, dolomitic rock, compact to porous, with irregular hollows. Many casts of corals, for the most part replaced by crystalline material and very obscurely shown. *Pocillopora*, *Seriatopora*, *Cœloria*, *Astræa*, *Madrepora*, and *Montipora*. Alcyonarian spicules. *Millepora*. Foraminifera not distinguishable, beyond encrusting *Polytrema planum*. *Cliona* borings. Branching *Lithothamnion*, very common.

(536A). Length 337 millims. Rock similar to the preceding. Many casts of corals; they are, as a rule, small forms belonging to *Stylophora*, an Astræan, *Madrepora*, *Montipora*, *Porites arenosa*, and *Astræopora*. Only *Orbitolites*, *Polytrema*, and *Amphistegina* recognised with a lens. Much branching and fragmental *Lithothamnion*. Casts of gastropods. Alcyonarian spicules.

(537A, 538A) [805]. Total length 305 millims. Greyish to greyish-brown, compact to minutely porous, occasionally cavernous. Casts of small corals; *Pocillopora*, *Seriatopora*, *Astræa*, *Orbicella pleiades*, Ellis, *Madrepora*, *Porites*. Alcyonarian spicules. Fragmental materials with *Miliolina*, *Orbitolites*, *Gaudryina*, *Carpenteria* (?), *Polytrema miniaceum*, and *Amphistegina*. Echinid spines. *Halimeda*. Encrusting and branching *Lithothamnion*.

(539A, 540A). Total length 382 millims. Greyish rock, like preceding. Numerous casts of corals. *Stylophora*, *Pocillopora*, *Orbicella pleiades*, *Madrepora*, and *Porites arenosa*. Detrital materials with *Orbitolites* and *Polytrema*. *Lithothamnion*. Casts of lamellibranchs.

(541A, 542A). Total length 294 millims. Greyish-brown, very hard, generally compact, dolomitic rock, with some irregular hollows. Casts of corals as in preceding cores; for the most part the corals are replaced by crystalline dolomite. *Stylophora*, *Pocillopora*, *Orbicella pleiades*, Astræan, *Madrepora*, and *Porites arenosa*. The only foraminifera recognised are *Orbitolites* and *Amphistegina*. Echinid spines. *Serpula*-tubes. Casts of lamellibranchs. *Halimeda*-joints. Encrusting and branching *Lithothamnion*.

Depth from Surface, 1015–1025 *feet*; *Distance Bored*, 10 *feet*; *Total Length of Core Obtained*, 8 *feet* 3 *inches*; *Numbers of Cores*, 543A–564A.

Solid cylindrical cores of whitish, greyish-white to greyish-brown, hard, dolomitic limestone, partly compact, partly porous with irregular cavities. The character of the rock is very similar to that of the cores immediately above; corals are present throughout, sometimes sufficiently numerous to form the larger part of the rock, while in other portions they are few, and small in proportion to the minute detrital fragments and foraminifera. They are, as usual, replaced by crystalline dolomite and scarcely recognizable. The following genera are present: *Stylophora* and *Pocillopora*, both very common, *Cœloria*, *Astræa*, *Orbicella*, *Fungia*, *Siderastræa*, *Madrepora*, *Porites*, *Montipora*, and *Astræopora* (?). *Millepora*, alcyonarian spicules. The foraminifera include *Textularia*, *Orbitolites*, *Carpenteria*, *Pulvinulina*, *Gypsina*, *Polytrema* and *Amphistegina*. Echinid spines, casts of gastropods and lamellibranchs. *Halimeda*-joints and *Lithothamnion*.

Details.

(543A–546A). Total length 304 millims. Greyish to greyish-brown, compact to porous. Mainly of corals, partly porous, partly infilled and replaced by crystalline material. *Stylophora*, *Pocillopora*, large *Cœloria* in position of growth; *Porites* and other forms not determinable. *Millepora*. *Orbitolites*, *Amphistegina*. Echinid spines. Casts of gastropods and lamellibranchs. *Lithothamnion*.

of *Madrepora*. Larger part of core of detrital materials in which alcyonarian spicules, echinid spines, *Orbitolites*, and a considerable amount of *Lithothamnion* can be distinguished.

(4–5). Whitish-grey, hard, minutely porous. Cast of *Prionastræa magnifica* (?) BLAINV., indications of *Porites* (?), and other corals too indistinct to be determined. Stem of *Lobophytum* and detached alcyonarian spicules. *Orbitolites*, *Amphistegina* and fragments of *Lithothamnion*.

(6). Greyish-white, speckled, minutely porous. Casts of *Pocillopora*, an Astræan (?), *Cyphastræa*, and a Fungid coral partly encrusted by *Polytrema*. Alcyonarian spicules, numerous. Greater part of the core consists of minute fragmentary materials with *Orbitolites*, *Amphistegina*, echinid spines and fragments of *Lithothamnion*.

(524A, 525A). Total length 299 millims. Greyish-brown, speckled, compact to porous, cavernous in places. Casts of *Seriatopora*, *Cyphastræa* (?), *Madrepora* and indications of other corals which are now replaced by crystalline dolomite. *Millepora*, about 70 millims. in length and wider than the core (58 millims.). Alcyonarian spicules numerous. Fine detrital materials with *Orbitolites* and other forms as in the preceding cores.

(526A, 527A). Total length 198 millims. Speckled greyish-brown, hard, compact to porous. Casts of *Seriatopora*, simple Astræan and other corals not recognisable. Cores chiefly of fragmental materials. Alcyonarian spicules numerous; *Orbitolites*, *Polytrema*, *Amphistegina*, branching *Lithothamnion*.

Depth from Surface, 1006–1015 *feet; Distance Bored*, 9 *feet; Total Length of Core Obtained*, 8 *feet* 6 *inches; Numbers of Cores*, 528A–542A.

Solid cylindrical cores of greyish-brown, hard, dense, dolomitic limestone, generally compact, but with occasional hollows, which are lined by concentric layers of crystalline dolomite. Corals are very generally present in all the cores, but only in some do they constitute the greater part of the rock. They are very imperfectly preserved, for the most part they have been replaced by the crystalline dolomite, leaving but scanty indications of their characters. The genera recognised are *Stylophora*, *Pocillopora*, *Seriatopora*, *Cœloria*, *Astræa* (?), *Orbicella*, *Cyphastræa*, *Madrepora*, *Montipora*, *Porites*, and *Astræopora*. *Millepora* and alcyonarian spicules are present. The foraminifera and detrital materials filling the areas between the corals include *Miliolina*, *Orbitolites*, *Gaudryina*, *Valvulina*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina*, *Heterostegina*; also echinid spines, *Serpula*-tubes, casts of gastropods and lamellibranchs, *Halimeda*-joints, branching and encrusting *Lithothamnion*.

DETAILS.

(528A–532A). Total length 318 millims. Speckled greyish-brown, compact to minutely porous, occasional irregular hollows. Casts of *Seriatopora* and other small corals now replaced by crystalline dolomite. *Millepora*, alcyonarian spicules, numerous. Larger part of the rock consists of detrital fragments with *Polytrema*, *Amphistegina*, echinid spines, and *Lithothamnion*.

(533A). Length 445 millims. Greyish-brown, hard dolomite with irregular hollows. Casts of *Pocillopora*, *Seriatopora*, *Cœloria*, *Cyphastræa* and *Madrepora*. Alcyonarian spicules. Foraminifera very obscurely shown, only *Orbitolites*, *Polytrema*, and *Amphistegina* recognised. Echinid spines. *Lithothamnion*.

(534A) [804]. Length 48 millims. Greyish-brown, hard, porous, dolomitic rock, principally of *Cœloria*, a continuation of the specimen in the preceding core. Alcyonarian spicules. The foraminifera shown in the microscopic section comprise, *Valvulina*, *Carpenteria*, *Gypsina*, *Polytrema miniaceum*, *Amphistegina*, and

Heterostegina. Echinid spines, *Serpula*, and nodular *Lithothamnion*. The small organisms and fragments are coated by numerous, thin successive layers of crystalline dolomite which cements them together.

(535A). Length 425 millims. Greyish-brown, very hard and dense, dolomitic rock, compact to porous, with irregular hollows. Many casts of corals, for the most part replaced by crystalline material and very obscurely shown. *Pocillopora*, *Seriatopora*, *Cœloria*, *Astræa*, *Madrepora*, and *Montipora*. Alcyonarian spicules. *Millepora*. Foraminifera not distinguishable, beyond encrusting *Polytrema planum*. *Cliona* borings. Branching *Lithothamnion*, very common.

(536A). Length 337 millims. Rock similar to the preceding. Many casts of corals; they are, as a rule, small forms belonging to *Stylophora*, an Astræan, *Madrepora*, *Montipora*, *Porites arenosa*, and *Astræopora*. Only *Orbitolites*, *Polytrema*, and *Amphistegina* recognised with a lens. Much branching and fragmental *Lithothamnion*. Casts of gastropods. Alcyonarian spicules.

(537A, 538A) [805]. Total length 305 millims. Greyish to greyish-brown, compact to minutely porous, occasionally cavernous. Casts of small corals; *Pocillopora*, *Seriatopora*, *Astræa*, *Orbicella pleiades*, ELLIS, *Madrepora*, *Porites*. Alcyonarian spicules. Fragmental materials with *Miliolina*, *Orbitolites*, *Gaudryina*, *Carpenteria* (?), *Polytrema miniaceum*, and *Amphistegina*. Echinid spines. *Halimeda*. Encrusting and branching *Lithothamnion*.

(539A, 540A). Total length 382 millims. Greyish rock, like preceding. Numerous casts of corals. *Stylophora*, *Pocillopora*, *Orbicella pleiades*, *Madrepora*, and *Porites arenosa*. Detrital materials with *Orbitolites* and *Polytrema*. *Lithothamnion*. Casts of lamellibranchs.

(541A, 542A). Total length 294 millims. Greyish-brown, very hard, generally compact, dolomitic rock, with some irregular hollows. Casts of corals as in preceding cores; for the most part the corals are replaced by crystalline dolomite. *Stylophora*, *Pocillopora*, *Orbicella pleiades*, Astræan, *Madrepora*, and *Porites arenosa*. The only foraminifera recognised are *Orbitolites* and *Amphistegina*. Echinid spines. *Serpula*-tubes. Casts of lamellibranchs. *Halimeda*-joints. Encrusting and branching *Lithothamnion*.

Depth from Surface, 1015–1025 *feet; Distance Bored*, 10 *feet; Total Length of Core Obtained*, 8 *feet* 3 *inches; Numbers of Cores*, 543A–564A.

Solid cylindrical cores of whitish, greyish-white to greyish-brown, hard, dolomitic limestone, partly compact, partly porous with irregular cavities. The character of the rock is very similar to that of the cores immediately above; corals are present throughout, sometimes sufficiently numerous to form the larger part of the rock, while in other portions they are few, and small in proportion to the minute detrital fragments and foraminifera. They are, as usual, replaced by crystalline dolomite and scarcely recognizable. The following genera are present: *Stylophora* and *Pocillopora*, both very common, *Cœloria*, *Astræa*, *Orbicella*, *Fungia*, *Siderastræa*, *Madrepora*, *Porites*, *Montipora*, and *Astræopora* (?). *Millepora*, alcyonarian spicules. The foraminifera include *Textularia*, *Orbitolites*, *Carpenteria*, *Pulvinulina*, *Gypsina*, *Polytrema* and *Amphistegina*. Echinid spines, casts of gastropods and lamellibranchs. *Halimeda*-joints and *Lithothamnion*.

DETAILS.

(543A–546A). Total length 304 millims. Greyish to greyish-brown, compact to porous. Mainly of corals, partly porous, partly infilled and replaced by crystalline material. *Stylophora*, *Pocillopora*, large *Cœloria* in position of growth; *Porites* and other forms not determinable. *Millepora*. *Orbitolites*, *Amphistegina*. Echinid spines. Casts of gastropods and lamellibranchs. *Lithothamnion*.

(547A–550A). Total length 382 millims. Greyish to greyish-brown, hard, cavernous rock. In the lower half the cores are mainly of coral casts. *Stylophora*, *Pocillopora*, *Madrepora*, *Porites*, and *Astræopora*. *Orbitolites*, and *Amphistegina*. Echinid spines. *Lithothamnion*.

(551A–553A) [806]. Total length 394 millims. Greyish-brown, in upper portion, cavernous, in lower, compact to minutely porous, dolomitic rock, very crystalline. It consists of corals and coarse detrital fragments of organisms, all greatly obscured. Casts of *Stylophora*, *Pocillopora*, *Astræa*, *Orbicella pleiades*, *Madrepora*, and *Porites*. *Orbitolites*, *Gypsina inhærens*, and *Amphistegina*. Echinid spines. *Halimeda*, branching *Lithothamnion*.

(554A, 555A). Total length 211 millims. Mottled greyish-white, minutely porous, with irregular hollows. Chiefly of coral casts. *Stylophora*, large, *Cœloria*, in position of growth; *Siderastræa* (?), *Porites*. Somewhat coarse detrital materials, with *Orbitolites*, *Polytrema planum*, *Amphistegina*; casts of lamellibranchs and turretted gastropods. *Lithothamnion*.

(556A). Length 193 millims. Greyish-brown, partly compact, partly porous, with irregular hollows. Largely of coral casts. Simple cylindrical Astræan, *Porites arenosa*, *Montipora*, *Millepora*. *Orbitolites*, numerous, *Polytrema planum*, *Amphistegina*. *Lithothamnion*.

(557A–559A). Total length 225 millims. Mottled greyish-white to brown, cavernous. Largely of coral casts. Cylindrical Astræan, *Fungia*, *Madrepora*, *Montipora* or *Porites*. Corals overgrown by *Polytrema planum*. Detrital materials with *Orbitolites*, *Gypsina*, *Amphistegina*; echinid spines, casts of lamellibranchs and gastropods, and *Lithothamnion*.

(560A–561A). Total length 391 millims. Whitish to mottled greyish-white, porous, with irregular hollows. The upper two-thirds consists of corals and coarse fragmental materials, the lower third principally of finer detritus with some corals. *Stylophora*, *Pocillopora*, *Astræa*, *Madrepora*, and *Montipora*. Coral casts encrusted by *Polytrema planum* and *Lithothamnion*. *Orbitolites*, *Carpenteria*, and *Amphistegina*. Casts of lamellibranchs and gastropods.

(562A–564A) [807]. Total length 277 millims. Whitish, hard, fine-grained, minutely porous, dolomitic limestone, with occasional hollows. Numerous casts of *Pocillopora*, simple Astræan, and *Montipora*. A microscopic section shows that the rock is chiefly a fine organic sediment cemented by crystalline dolomite. It contains *Orbitolites*, *Textularia rugosa*, *Carpenteria*, *Pulvinulina*, *Gypsina inhærens*, *Polytrema miniaceum*, and *Amphistegina*. Echinid spines. Small alcyonarian spicules. *Leptoclinum* stellates. Fragments of *Lithothamnion*. Casts of gastropods.

Depth from Surface, 1025–1034 *feet*; *Distance Bored*, 9 *feet*; *Total Length of Core Obtained*, 8 *feet* 10 *inches*; *Numbers of Cores*, 565A–583A$_1$.

Solid cylindrical cores of greyish-white to greyish-brown, hard, dolomitic limestone. The rock is in part porous, in part compact, and it is not infrequently cavernous or with small irregular hollows where, as a rule, corals have been partially destroyed. In general characters the rock resembles that above; many of the cores are largely composed of coral casts and the areas between are filled with foraminifera and somewhat coarse organic fragments which are cemented by crystalline dolomite. With the exceptions of *Fungia* and *Siderastræa*, which have not been observed, the same genera of corals occur as in the preceding, the commonest forms being *Pocillopora*, *Cœloria*, *Orbicella*, and *Porites*. *Millepora* and *Lobophytum* still continue. Excepting *Textularia* and *Pulvinulina*, which were not observed, the cores contain the same genera of foraminifera as those above, with the addition of *Heterostegina*, which is here very common. The detrital fragments are likewise the

same as those last noted; *Halimeda* only occurs sparsely. *Cliona* borings are present.

Details.

(565A). Length 313 millims. Greyish-white, minutely porous, with some irregular hollows. Coral casts present throughout. *Prionastræa magnifica*; conical or cylindrical corals, growing either singly or in small clumps, *Madrepora*, *Montipora* and *Porites* (?). Alcyonarian spicules. *Orbitolites*, *Polytrema planum*, *Amphistegina*. Casts of lamellibranchs and gastropods. Fragments of *Lithothamnion*.

(566A, 567A). Total length 265 millims. Greyish-white, porous. Casts of *Pocillopora*, simple cylindrical Astræan, *Madrepora*, *Porites*. Alcyonarian spicules. Greater part of core consists of detrital materials with *Orbitolites*, common, *Carpenteria*, *Amphistegina*. Echinid spines. Casts of lamellibranchs and gastropods. *Lithothamnion*.

(568A). Length 294 millims. Greyish-white, porous, with irregular hollows. Largely of coral casts, *Pocillopora*, *Orbicella*, cylindrical Astræan, *Madrepora*, *Porites* common. Alcyonarian spicules. Detrital fragments with the same genera of foraminifera and other organisms as in the preceding. Infilled *Cliona* borings.

(569A, 570A). Total length 363 millims. Greyish-brown, compact to minutely porous, efflorescent in places. Chiefly of corals. *Pocillopora*, *Cœloria*, Astræan, *Madrepora*, *Porites* common, and *Astræopora*. *Millepora*, alcyonarian spicules. *Carpenteria*, *Amphistegina*; casts of lamellibranchs and gastropods; branching *Lithothamnion*.

(571A, 572A). Total length 303 millims. Greyish-white, porous, and cavernous. Cores chiefly of corals, *Pocillopora*, *Cœloria*, *Orbicella pleiades*, and *Madrepora*. *Millepora*, mass of *Lobophytum*, and detached spicules. *Polytrema planum* and *Amphistegina*. Echinid spines. Casts of gastropods. Branching *Lithothamnion*.

(573A–575A) [808]. Total length 151 millims. Greyish-white, porous. Largely of coral casts. *Pocillopora*, *Orbicella pleiades*, *Madrepora* and *Astræopora*. *Millepora*, alcyonarian spicules. *Orbitolites*, *Carpenteria*, *Gypsina*, *Amphistegina*, and *Heterostegina*; echinid spines. *Cliona* borings. *Lithothamnion*. A microscopic section of the *Astræopora* shows that the coral structure has been replaced by crystalline dolomite, while the original interspaces are now either infilled with consolidated sediment or are merely lined with crystals.

(576A) [809]. Length 316 millims. Greyish-brown, speckled, minutely porous, hardly any hollows. One or two examples of *Pocillopora* and *Orbicella pleiades*: the rock, excepting these coral casts, is throughout of minute organic fragments with *Orbitolites*, common, *Carpenteria*, *Calcarina*, *Gypsina vesicularis*, *Polytrema miniaceum*, *Amphistegina*, and *Heterostegina*, common. Echinid spines. Casts of gastropods. *Halimeda* and fragments of *Lithothamnion*. Many of the small irregular detrital fragments are now without structure, being replaced by crystalline dolomite; it is possible that they are altered pieces of corals. The fragments are cemented into hard rock by crystalline dolomite.

(577A, 578A) [810]. Total length 248 millims. Greyish-white, speckled, minutely porous. Numerous coral casts; *Pocillopora*, *Cœloria*, *Astræa*, *Orbicella pleiades*, and *Madrepora contecta*. Alcyonarian spicules. Somewhat coarse fragmental materials with *Orbitolites*, *Carpenteria*, *Gypsina*, *Polytrema planum*, *Amphistegina*, and *Heterostegina*. Echinid spines. Fragments of *Lithothamnion*.

(579A–582A) [600]. Total length 298 millims. Greyish-white to greyish-brown, compact to porous. Largely of corals belonging to *Stylophora*, *Pocillopora*, and *Cœloria*. Somewhat coarse detrital materials containing the same foraminifera and other organisms as in the preceding core.

($583A_1$). Length 127 millims. Greyish-brown, minutely porous, with a large hollow extending the length of the core, where part of a large specimen of *Orbicella* has been removed. About half the core consists of detrital materials with *Orbitolites*, *Polytrema planum* and *Amphistegina*. Echinid spines. *Halimeda*, *Lithothamnion*.

Depth from Surface, 1034–1044½ *feet ; Distance Bored*, 10½ *feet ; Total Length of Core Obtained*, 10 *feet* 5 *inches ; Numbers of Cores*, $583A_2$–594A.

Solid cylindrical cores of greyish to greyish-brown, hard, dolomitic limestone. The rock varies from compact to minutely porous, with occasional hollows. Casts of corals are generally present, in some cores they predominate, while in others the rock consists chiefly of small organic fragmentary materials with foraminifera. The corals for the most part belong to the same genera as in the preceding cores: *Stylophora*, *Pocillopora*, *Seriatopora*, *Astræa*, *Cœloria*, *Orbicella*, *Madrepora*, and *Porites*; also *Millepora* and alcyonarian spicules. The foraminifera comprise *Miliolina*, *Orbitolites*, *Textularia*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, *Heterostegina*, and, rarely, *Cycloclypeus*. Echinid spines. Casts of gastropods and lamellibranchs, including *Lithodomus*; *Halimeda*, and *Lithothamnion*. Borings of *Cliona*.

Details.

($583A_2$). Length 143 millims. Greyish-brown, minutely porous, with irregular hollows. Casts of *Pocillopora*, *Astræa*, and *Porites arenosa*. Larger part of core of fragmental material, with *Orbitolites* and *Amphistegina*. Echinid spines. Casts of lamellibranchs. *Lithothamnion*.

(584A) [811]. Length 334 millims. Greyish, hard, minutely porous, with a few hollows. Coral casts small generally; they belong to *Pocillopora*, *Seriatopora*, *Astræa*, *Orbicella pleiades*, *Madrepora*, and *Porites*. *Millepora*. Alcyonarian spicules. The larger part of the core consists of somewhat coarse fragmental materials, with *Orbitolites complanata*, *Textularia*, *Gypsina inhærens*, *Polytrema*, *Amphistegina*, *Heterostegina*, and *Cycloclypeus* (worn specimen seen in the microscopic section). Echinid spines. Casts of gastropods and lamellibranchs. *Lithothamnion*. The interspaces between the fragments only partially filled with the crystalline dolomitic matrix.

(585A). Length 722 millims. Greyish to greyish-brown, speckled, hard, minutely porous. The core has been divided transversely into five pieces of about equal length. The rock is practically of the same character throughout; it is very largely of somewhat coarse fragmental materials, with foraminifera and casts of small corals, not occupying much space. They belong to *Stylophora*, *Pocillopora*, *Seriatopora*, *Cœloria*, and *Porites*. *Millepora*. The foraminifera include *Orbitolites*, *Gypsina*, *Polytrema*, *Amphistegina* and *Heterostegina*. Echinid spines. Casts of shells and *Lithothamnion* in small fragments.

(586A). Length 140 millims. Greyish-brown, minutely porous, and cavernous. Rock mainly of coral casts. *Stylophora*, *Pocillopora*, *Orbicella*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Casts of lamellibranchs, *Lithothamnion*.

(587A). Length 286 millims. Greyish-brown, minutely porous, and with irregular hollows. The upper half of this core is mainly of casts of *Orbicella*, with some *Seriatopora*, while the lower part is chiefly fragmental, with the same foraminifera and other organic remains as in the core above.

(588A). Length 172 millims. Greyish-brown, minutely porous, with irregular hollows. Largely of coral casts, some hollow, others solidly infilled with crystalline dolomite. The corals belong to *Stylophora*, *Pocillopora*, *Orbicella pleiades*, and *Cœloria*. *Orbitolites*. Casts of lamellibranchs. *Lithothamnion*.

(589A). Length 90 millims. Greyish-brown, porous to compact, large hollow where coral has been in part removed. Core principally consists of casts of *Pocillopora* and *Cœloria*. Alcyonarian spicules. Echinid spines. *Orbitolites*. *Cliona* borings.

(590A) [812]. Length 377 millims. Greyish, speckled, fine-grained, minutely porous to compact. With the exception of casts of *Pocillopora* and *Orbicella pleiades* in the upper part, the core is nearly altogether of fine fragmental materials, with foraminifera, alcyonarian spicules, echinid spines, casts of gastropods

and small pieces of corals, and *Lithothamnion*, cemented by crystalline dolomite into a very hard rock. The foraminifera include *Miliolina*, *Orbitolites complanata*, *Textularia*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Cycloclypeus*.

(591A). Length 172 millims. Greyish-brown, speckled, compact to porous, cavernous in places. Hollow casts of *Stylophora*, also casts of *Pocillopora* throughout the core, probably in position of growth some are very much riddled with *Cliona* borings. *Madrepora*. *Orbitolites* abundant; *Gypsina*, *Polytrema planum*, and *Amphistegina*. Echinid spines. Casts of gastropods. Encrusting and fragmental *Lithothamnion*.

(592A). Length 271 millims. Rock similar to preceding. Casts of *Pocillopora*, numerous, some hollow, others solidly infilled with crystalline dolomite. *Cœloria*, *Orbicella*, *Porites arenosa*, and other perforate corals. Fragmentary materials, with foraminifera and other organisms similar to the preceding, with *Halimeda* in addition.

(593A, 594A) [813]. Total length 405 millims. Greyish-brown, speckled, hard dolomite. As in the two cores above, the principal coral here is *Pocillopora*, mostly as hollow casts, greatly riddled by *Cliona* borings; other examples are solidly replaced by crystalline dolomite; *Stylophora* accompanies it; the corals not infrequently are overgrown by *Polytrema planum*. Simple cylindrical Astræan, also *Porites*. *Millepora* and alcyonarian spicules. The fragmental part of the rock contains the same foraminifera (except *Textularia* and *Cycloclypeus*), and the same detrital organisms as No. 590A. *Halimeda*, showing structure, not uncommon.

Depth from Surface, 1044½–1053 *feet; Distance Bored*, 8½ *feet; Total Length of Core Obtained*, 7 *feet* 7 *inches; Numbers of Cores*, 595A–607A.

Solid cylindrical cores of greyish to greyish-brown, hard, dolomitic limestone. The rock is in part compact, in part minutely porous, with hollows occasionally. Corals are present in all the cores, but generally they are small, and the cores frequently consist, to a very large extent, of the fragmental materials previously mentioned. In some cores, however, the corals predominate. The genera present are *Stylophora*, *Pocillopora*, *Seriatopora*, *Astræa*, *Orbicella*, *Madrepora*, *Porites*, and an undetermined perforate form. *Millepora* and alcyonarian spicules still occur. The fragmental materials are generally fine-grained; the following foraminiferal genera are included with the other organisms: *Orbitolites*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Echinid spines, casts of lamellibranchs and gastropods. *Cliona* borings, *Serpula*-tubes, *Halimeda*, and *Lithothamnion* likewise occur. Crystalline dolomite cements the various fragmentary materials into a very hard rock.

DETAILS.

(595A, 596A). Total length 218 millims. Greyish-brown, porous, cavernous in places. Coral casts fairly numerous; *Stylophora*, *Pocillopora*, *Orbicella*, *Madrepora*, and *Porites*. Alcyonarian spicules. The detrital materials contain the same foraminifera and other organisms mentioned above.

(597A). Length 305 millims. Speckled, greyish-brown, compact to minutely porous. With the exception of casts of *Seriatopora*, and of a small *Madrepora*, the core consists of foraminifera and detrital materials. *Orbitolites* abundant, *Polytrema* and *Amphistegina*. Echinid spines. *Halimeda*. Encrusting and branching *Lithothamnion*.

(598A). Length 192 millims. Greyish, hard, compact to porous, cavernous in places where corals have

been removed. Numerous casts of small corals are distributed through the core, including *Pocillopora*, *Seriatopora*, and *Madrepora*, surrounded by thick layers of *Polytrema planum*, with others not determinable. *Millepora*. Alcyonarian spicules. *Orbitolites*, *Gypsina*, *Amphistegina*. Echinid spines. Casts of lamellibranchs and gastropods. *Lithothamnion*. *Cliona* borings.

(599A, 600A). Total length 274 millims. Speckled greyish-brown, fine-grained, compact to porous dolomite, with occasional hollows. Casts of small corals; *Stylophora*, *Pocillopora*, *Seriatopora*, *Madrepora*, and undetermined perforate corals. Alcyonarian spicules. Detrital materials, including the same foraminifera and other organisms as in the preceding core, with the addition of *Heterostegina*.

(601A). Length 269 millims. Rock similar to preceding. Casts of small corals belonging to *Stylophora*, *Seriatopora*, *Astræa* and *Porites*. The larger part of the core consists of foraminifera and fragmentary detritus; *Orbitolites*, *Polytrema* and *Amphistegina*. Echinid spines, *Serpula*-tubes. *Lithothamnion*.

(602A). Length 150 millims. Speckled greyish-brown, minutely porous. At the top of the core there is a cast of *Stylophora*; with this exception the rock consists of the same foraminifera as in the preceding, with the addition of *Gypsina*. Echinid spines. Fragments of *Lithothamnion*.

(603A) [814]. Length 205 millims. Rock like preceding. Cast of small *Astræa* and *Millepora*. Alcyonarian spicules. Core chiefly of foraminifera and fragmental materials. *Orbitolites*, *Carpenteria*, *Polytrema planum*, prominent, *Gypsina inhærens*, *Amphistegina* and *Heterostegina*. Echinid spines and plates, common and well preserved. Fragments of *Lithothamnion*. *Halimeda*.

(604A, 605A). Total length 256 millims. Rock similar to preceding. Casts of small examples of *Stylophora*, *Pocillopora* and *Porites*. *Millepora*. Corals generally surrounded with *Polytrema planum*, showing the structure distinctly. Larger part of core consists of *Orbitolites*, *Amphistegina*, casts of gastropods, and fragments of *Lithothamnion*. *Cliona* borings.

(606A) [815]. Length 252 millims. Greyish-brown, mottled, porous, with occasional hollows. Core largely of corals: *Pocillopora*, *Astræa*, and a perforate coral, which I have not been able to determine. Corals encrusted by thick whitish layers of *Polytrema planum*. Alcyonarian spicules. The foraminifera include *Orbitolites*, *Planorbulina*, *Carpenteria*, *Amphistegina*, *Heterostegina*, as well as the *Polytrema* mentioned. Echinid spines. Casts of lamellibranchs. *Lithothamnion*.

(607A). Length 148 millims. Greyish-brown, minutely porous, with occasional hollows. *Stylophora*, *Pocillopora*, *Orbicella*. Thick layers of *Polytrema planum*. Echinid spines. *Amphistegina*. *Lithothamnion*.

Depth from Surface, 1053–1066 *feet*; *Distance Bored*, 13 *feet*; *Total Length of Core Obtained*, 9 *feet* 9 *inches*; *Numbers of Cores*, 608A–627A.

Solid cylindrical cores of greyish, greyish-white to greyish-brown, dolomitic limestone; from about the horizon of 1060 feet there is a less amount of magnesian carbonate in the rock than previously; as a consequence of this, the foraminifera are much better preserved, but the corals continue in the same unfavourable state of preservation; they have been either partially dissolved away, or they are replaced and infilled with crystalline matrix. The cores are frequently cavernous, and the hollows are lined with concentric layers of crystalline calcite and dolomite. Corals are generally distributed in the rock, but not equally; in some cores there are only a few small casts, while in others the rock is to a large extent composed of them. They belong to *Stylophora*, *Pocillopora*, *Seriatopora*, Astræan, genus undetermined, *Orbicella*, *Psammocora*, *Madrepora*, *Montipora*, and *Porites*. *Lobophytum* and detached alcyonarian spicules. Foraminifera are very numerous and well shown;

they comprise *Miliolina*, *Orbitolites*, *Textularia*, *Globigerina*, *Planorbulina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina* and *Heterostegina*. Echinid spines. Casts of gastropods and lamellibranchs. *Lithothamnion*. In one of the cores there is a fragment of fish-bone or spine, the first and only fragment of a vertebrate skeleton which has been met with.

Details.

(608A). Length 240 millims. Greyish-brown, compact to minutely porous, with a few small hollows. Casts of small corals fairly numerous; *Stylophora*, *Pocillopora*, *Orbicella*, *Madrepora* and *Porites*. The foraminifera belong to *Orbitolites*, *Gypsina*, *Polytrema* and *Amphistegina*. Amongst the fragmentary materials there are echinid plates and spines, small gastropods and *Lithothamnion*.

(609A, 610A). Total length 522 millims. Rock similar to the preceding, but also with one or two large hollows. The corals and other organisms very obscurely shown. Casts of *Stylophora*, *Pocillopora*, *Orbicella* and *Porites*. With the exception of *Orbitolites*, which was not observed, the foraminifera and the other fragmentary organisms are the same as in the core above. The cavities lined with banded crystalline dolomite.

(611A–617A). Total length 671 millims. Rock greyish-brown, hard, crystalline and compact, and in places very cavernous. By far the larger part of these cores appears to consist of foraminiferal and fragmental remains; coral casts are present occasionally, but they are now so altered and replaced by crystalline material, that, beyond *Montipora* and a simple Astræan, they cannot be determined. Alcyonarian spicules are present. The foraminifera include *Orbitolites*, *Planorbulina*, *Gypsina*, *Polytrema*, *Amphistegina* and *Heterostegina*. Echinid spines and plates; casts of gastropods; fragments of *Lithothamnion*.

(618A–620A) [601, 816.] Total length 252 millims. Greyish-white to greyish-brown, mottled, mostly compact, with occasional hollows. With the exception of some layers of *Montipora*, overgrown by *Polytrema planum*, these cores chiefly consist of foraminifera, detrital fragments and fine sediment, with numerous minute detached rhombohedral crystals [816]. *Lobophytum* and detached alcyonarian spicules. The foraminifera are well preserved, and show their structure in microscopic sections. The following were determined by Mr. Chapman:—*Miliolina*, 2 sp., *Orbitolites*, *Textularia*, *Globigerina bulloides*, *Planorbulina larvata*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina* and *Heterostegina*. Echinid spines. *Lithothamnion*.

(621A) [817]. Length 245 millims. Greyish-white, compact, cavernous in places. The core contains some obscure casts of perforate corals, and the same kinds of foraminifera (with the exception of *Textularia* and *Globigerina*) and detrital organisms as in the preceding. There is also a fragment, about 20 millims. in length, of a fish-bone or spine. *Serpula*.

(622A). Length 231 millims. Greyish-brown, with white flecks in places, hard, mostly compact with some irregular hollows. The core chiefly consists of casts of corals, now solidly replaced and infilled with crystalline dolomitic limestone. *Stylophora*, *Pocillopora*, simple Astræan, *Montipora* and *Psammocora*. *Lobophytum*. The foraminifera include *Orbitolites*, *Planorbulina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. *Lithodomus*. Casts of gastropods.

(623A) [818, 819]. Length 222 millims. Greyish-brown, compact generally, but with some porous areas and occasional hollows. Core largely of corals, in the same condition as in the preceding. *Stylophora*, *Pocillopora*, *Seriatopora*, *Orbicella*, simple Astræan, and *Psammocora* with some obscure perforate corals. Specimen of *Lobophytum* overgrown by *Polytrema planum*, the spicules in it retaining their minute structure. The foraminifera belong to *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina*, *Amphistegina*, and *Heterostegina*. Echinid spines. Casts of lamellibranchs and gastropods. Nodular growths of *Lithothamnion*.

(624A, 625A). Length 194 millims. Brownish-grey, mostly compact and crystalline; a few small

hollows. With the exception of one or two casts of *Stylophora* and *Orbicella*, the cores are chiefly foraminiferal and detrital. The same foraminifera as in the preceding core, except *Carpenteria* and *Calcarina*, which were not noticed. *Serpula*-tubes. *Cliona* borings. Encrusting and nodular *Lithothamnion*.

(626A, 627A). Total length 356 millims. Greyish-brown, flecked with white, for the most part compact and crystalline. There are some casts of *Pocillopora*, simple Astræan and perforate corals, too poorly preserved for identification, in the lower core, but the larger part of the rock consists of foraminifera and detrital organic fragments. *Orbitolites* and *Amphistegina* are very numerous; *Gypsina*, *Polytrema*, and *Heterostegina* are also plentiful. Casts of gastropods.

Depth from Surface, 1066–1075 *feet; Distance Bored*, 9 *feet; Total Length of Core Obtained*, 7 *feet* 9 *inches; Numbers of Cores*, 628A–643A.

Solid cylindrical cores of greyish-brown, hard, generally compact, dense and crystalline, dolomitic limestone. With few exceptions the rock is somewhat poor in corals, this may in part arise from their having been removed or replaced by crystalline dolomite; those that remain are frequently so indistinctly preserved that it is not practicable to determine the genus to which they belong. As a rule, the corals are only small casts of *Stylophora* and *Pocillopora*, with larger specimens of *Orbicella*; there is also an example of *Euphyllia* or an allied genus in one of the lower cores, the first form of this group which has been met with. Perforate corals are not uncommon, but except *Madrepora* they cannot be recognised. *Millepora* is not infrequent, and alcyonarian spicules are very numerous throughout these cores. The great mass of the rock consists of foraminifera and other detached organisms and fragments which are cemented into solid rock by crystalline dolomite. The foraminifera are of the usual types: *Orbitolites*, *Textularia*, *Carpenteria*, *Gypsina*, *Polytrema*, *Amphistegina*, *Heterostegina*, and one imperfect specimen is considered by Mr. CHAPMAN to be a *Cycloclypeus*. Echinid spines. *Lithothamnion*, encrusting and in nodules.

DETAILS.

(628A). Length 357 millims. Greyish-brown, compact to minutely porous, with occasional hollows where corals have been dissolved out. This core consists chiefly of corals, belonging to *Stylophora*, *Pocillopora*, a specimen of *Orbicella pleiades*, 160 millims. in height, simple Astræan, *Madrepora* (?) and other perforate corals. *Millepora*, also alcyonarian spicules. The foraminifera include *Orbitolites*, *Textularia*, *Gypsina*, *Polytrema*, and *Amphistegina*. Echinid spines. *Lithothamnion*.

(629A) [820]. Length 113 millims. Greyish-brown, crystalline dolomite, similar to the preceding. The rock is almost wholly foraminiferal and fragmental, and the organisms are similar to those in the preceding core, with the exception that *Textularia* does not occur, whilst fragments of *Carpenteria* are present. Alcyonarian spicules.

(630A). Length 215 millims. Greyish-brown, compact to minutely porous. Casts of *Pocillopora*, simple Astræan, and fragments of perforate corals. Alcyonarian spicules abundant. Greater part of core foraminiferal and detrital, with *Orbitolites*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Fragments o *Lithothamnion*.

(631A–633A). Total length 276 millims. Rock similar to preceding. Casts of *Pocillopora* and perforate corals, which are now replaced and infilled with the crystalline dolomite. Alcyonarian spicul foraminifera, and *Lithothamnion* as in the preceding core.

Madrepora and other perforates. *Millepora*, alcyonarian spicules, abundant. Foraminifera, shown in microscopic sections, belonging to *Orbitolites*, *Carpenteria*, *Gypsina inhærens*, *Polytrema planum*, and *Amphistegina*. *Cliona* borings. *Lithothamnion*.

(645A). Length 103 millims. Brownish core, compact to porous, with large hollows where perforate corals have been removed. Rock now principally of crystalline dolomite, only alcyonarian spicules can be distinguished in it.

(646A) [823]. Length 379 millims. Greyish-brown, mostly compact, with one large and some smaller hollows. In most of the rock the organisms have been replaced by the crystalline dolomite; the only coral recognised is a portion of a small *Fungia*, but there are traces of other forms. Alcyonarian spicules. The same foraminifera as in the preceding core (644A) (with the exception of *Carpenteria*), and in addition, *Planorbulina*, *Pulvinulina* and *Calcarina*. Echinid spines. Casts of gastropods. *Halimeda*. Encrusting *Lithothamnion*.

(647A). Length 230 millims. Rock similar to preceding. A few hollow spaces, due to the removal of corals, the larger part of the core consists of foraminifera and fragmental material cemented by crystalline dolomite. *Planorbulina*, *Polytrema* and *Amphistegina* are the only forms recognisable with a lens. Echinid spines.

(648A). Length 540 millims. The core has been cut transversely into four pieces. The rock is hard, of a light greyish-brown, in places speckled white, compact generally, but in certain areas porous and with a few hollows, where corals have been present, these spaces are now surrounded by the *Polytrema planum* and *Lithothamnion*, which originally encrusted the corals. The only forms distinguishable are *Stylophora* and *Seriatopora*. The core appears chiefly to consist of *Orbitolites*, *Planorbulina*, *Amphistegina*, *Heterostegina*, together with echinid spines.

(649A). Length 308 millims. Greyish-brown, porous, with numerous irregular hollows, which are lined and partially infilled with the banded crystalline dolomite. The only organisms recognisable with a lens are *Seriatopora*, fragments of perforate corals, and *Millepora*. *Amphistegina*. Echinid spines and *Lithothamnion*.

(650A–652A). Total length 260 millims. Rock like preceding. Casts of *Stylophora*, *Pocillopora*, *Orbicella*, and simple Astræan coral. Corals encrusted by *Polytrema planum* and by *Lithothamnion*. *Cliona* borings.

(653A, 654A). Total length 175 millims. Rock similar to preceding, very cavernous. Casts of *Stylophora*, *Seriatopora* and *Orbicella pleiades*. *Amphistegina*, *Lithothamnion*.

(655A, 656A). Total length 201 millims. Greyish, hard, compact to porous, with occasional hollows. Casts of *Stylophora*, *Astræa* (?) and perforate corals. *Orbitolites*, *Polytrema* (?) and *Amphistegina*. Echinid spines; *Lithothamnion*.

(657A, 658A). Total length 127 millims. Greyish-brown, porous in part with occasional large hollows. Casts of Astræan and of perforate coral. *Millepora*, *Amphistegina*, *Lithothamnion*.

(659A). Length 263 millims. Greyish-brown, porous and cavernous. Probably corals originally occupied most of the hollow spaces, but only *Seriatopora* and traces of perforate corals are now distinguishable. *Textularia*. Echinid spines. Several casts of lamellibranchs. *Lithothamnion*. Rock highly crystalline.

(660A, 661A). Length 235 millims. Rock like preceding. The crystallisation has obliterated nearly all the organisms except echinid spines.

Depth from Surface, 1087–1100 *feet; Distance Bored*, 13 *feet; Total Length of Core Obtained* 12 *feet* 2 *inches; Numbers of Cores* 662A–682A.

Solid cylindrical cores of grey to greyish-brown, hard dolomitic limestone. The rock is in places minutely porous where small organisms or fragments have been removed, and frequently cavernous, or with large hollows arising from the removal of

corals, or molluscan shells. The upper cores are generally very similar to those described above; the rock is very crystalline, and the organisms—both corals and foraminifera—are nearly obliterated. In the lower 5 feet of this part of the boring corals are more numerous, but still in bad condition. The genera present are *Stylophora*, *Pocillopora*, *Cœloria*, *Orbicella*, *Astræa*, *Fungia*, *Madrepora*, *Porites*, and other perforates. *Millepora*, alcyonarian spicules. Foraminifera and fragmental material form the larger mass of the rock in the higher cores, while in some of the lower they are subordinate to the corals. The following have been recognised: *Miliolina*, *Orbitolites*, *Textularia*, *Planorbulina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Echinid spines. *Serpula*-tubes. Casts of gastropods and lamellibranchs. *Halimeda* (not common), *Lithothamnion*.

DETAILS.

(662A–664A). Total length 346 millims. Greyish-brown, dense, dolomitic limestone, with occasional hollows. Organic structures largely obliterated; the only forms recognisable with a lens are *Amphistegina*, *Polytrema*, echinid spines, and fragments of *Lithothamnion*.

(665A) [824]. Length 196 millims. Greyish-brown, compact to porous. Organisms very indistinct, apparently almost entirely foraminifera and fragmental *débris*; only a small branching *Madrepora* shown in the section, together with *Orbitolites*, *Textularia rugosa*, *Calcarina*, *Gypsina inhærens*, *Amphistegina*, echinid spines, and casts of lamellibranchs. *Halimeda*, fragments of *Lithothamnion*.

(666A–667A). Total length 246 millims. Rock like the preceding. Specimens of *Orbicella pleiades* throughout the cores. *Orbitolites*, *Amphistegina* (numerous). Echinid spines, casts of lamellibranchs, and fragments of *Lithothamnion*.

(668A). Length 228 millims. Speckled, greyish-brown, hard, porous. The only remains of corals recognised are casts of a small perforate, the core principally consists of *Orbitolites*, *Polytrema planum*, *Amphistegina*, echinid spines; casts of lamellibranchs and *Lithothamnion*.

(669A, 670A). Length 140 millims. Rock similar to preceding. The only organisms determinable are *Orbitolites*, *Amphistegina*, and echinid spines, together with casts of lamellibranchs.

(671A, 672A). Total length 275 millims. Greyish-brown, porous and cavernous, the hollows due to the removal of corals and lamellibranch shells. Casts of *Astræa*, *Fungia*, and *Porites* (?); probably more than half the cores of corals originally. *Orbitolites*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Echinid spines.

(673A, 674A). Total length 137 millims. Rock similar to preceding. The large hollows due to corals, which are now too far replaced for determination. *Amphistegina*, echinid spines. Casts of lamellibranchs.

(675A) [825]. Length 87 millims. Greyish-brown, minutely porous, some hollows. Cast of perforate coral. Alcyonarian spicules. The core is almost entirely composed of foraminifera and detrital materials. The microscopic section shows the following forms, determined by Mr. CHAPMAN: *Miliolina*, *Orbitolites*, *Textularia*, *Globigerina*, *Carpenteria*, *Calcarina*, *Gypsina inhærens*, *Polytrema planum*, *Amphistegina*, and *Heterostegina*. Echinid spines. *Halimeda*-joints somewhat rare. *Lithothamnion*.

(676A). Length 401 millims. Greyish-brown, porous to compact, with occasional small hollows. Casts of *Pocillopora*, simple cylindrical Astræan, *Madrepora contecta* (?), and perforate corals, which are too much altered for determination. The larger part of the core consists of foraminifera and fragmental organic materials. *Gypsina*, *Polytrema planum*, *Amphistegina Lessonii* very numerous. Echinid spines. Casts of gastropods. *Lithothamnion*.

(677A) [826]. Length 235 millims. Speckled, greyish-brown, compact to porous, with occasional hollows. Core chiefly consists of coral casts, for the most part now solidly infilled with crystalline

dolomite. *Pocillopora*, *Orbicella pleiades*, *Madrepora*, and other perforate corals. *Millepora*, *Orbitolites*, *Textularia*, *Planorbulina*, *Carpenteria*, *Gypsina inhærens*, *Polytrema planum*, *Amphistegina* very common, and *Heterostegina*. Echinid spines and plates. Casts of lamellibranchs. *Halimeda*-joints. Areas of fine organic sediment shown in microscopic section, with stellates of *Leptoclinum* (?).

(678A). Length 718 millims., divided transversely into five pieces, marked 1–5. Core greyish to greyish-brown, speckled, hard, compact to minutely porous, some small hollows, and in the lower cores (4–5) larger cavities, where corals have been dissolved away. The pores and hollows are lined with banded crystalline dolomite. Corals are present throughout the core, and in places they form the chief part of it. They belong to *Stylophora*, *Pocillopora*, *Cœloria*, simple Astræan, *Madrepora*, *Porites*, and other perforate forms. *Millepora*. The corals are usually overgrown by *Polytrema planum* and by *Lithothamnion*. The only foraminifera recognisable by the lens are *Orbitolites* and *Amphistegina*. Echinid spines. Casts of gastropods. *Halimeda* (?).

(679A). Length 282 millims. Rock similar to the preceding. The core largely consists of casts of corals, now for the most part infilled with the crystalline matrix, and very indistinct. They chiefly belong to *Stylophora* and *Porites*, with occasionally *Madrepora*. The corals are encrusted by *Lithothamnion* and *Polytrema*. *Amphistegina*.

(680A, 681A) [827]. Total length 214 millims. Greyish to greyish-brown, mottled, compact to porous, occasional hollows. Cores chiefly of corals. *Stylophora*, *Cœloria*, bored by *Lithodomus*, and *Porites*. The corals encrusted with thick layers of *Polytrema planum*. Alcyonarian spicules. In the detrital mud surrounding the coral casts there are *Orbitolites*, *Planorbulina larvata*, *Carpenteria*, *Gypsina discus*, and *Amphistegina*. Echinid spines. *Cliona* borings.

(682A) [828]. Length 160 millims. Greyish-brown, compact to porous, with several hollows. Core largely of corals. *Cœloria* and *Porites*. *Millepora*. Alcyonarian spicules. Encrusting *Polytrema* and *Lithothamnion*. *Calcarina*, *Amphistegina*. The interspaces of *Cœloria* filled with fine sedimentary material containing *Leptoclinum* stellates. *Cliona* borings.

Depth from Surface, 1100–1114½ *feet; Distance Bored*, 14½ *feet; Total Length of Core Obtained*, 12 *feet* 10 *inches; Numbers of Cores*, 683A–709A.

Solid cylindrical cores of whitish, greyish-white, to greyish-brown, hard, dolomitic limestone, compact to porous, cavernous in places, occasionally efflorescent. The cores consist largely of corals to the horizon of 1109 feet, where there is a change; the rock becomes whitish, more porous, and it is mainly composed of foraminifera, with only small corals here and there. This continues to nearly the bottom of the boring, with exceptional portions where corals are more numerous. The preponderating corals are of the family *Astræidæ*, belonging to *Cœloria*, *Astræa*, and *Orbicella*. Other forms present are *Stylophora*, *Pocillopora*, *Cyphastræa*, Fungid, genus uncertain; *Madrepora*, *Porites*, and a perforate coral, of uncertain affinity. *Millepora* is not uncommon, and occurs in position of growth in the lower cores; also *Lobophytum* and alcyonarian spicules. The foraminifera include *Miliolina*, *Orbitolites*, *Textularia*, *Globigerina*, *Planorbulina*, *Carpenteria*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. There are also echinid spines, *Serpula*-tubes, casts of lamellibranchs and gastropods, *Cliona* borings, and *Lithothamnion*.

DETAILS.

[683A 684A]. Total length 355 millims. Greyish to greyish-brown, mottled, compact to minutely

(703A) [832]. Length 329 millims. Whitish, porous, hard. Small cast of *Stylophora*, and simple coral, genus uncertain. Laminate *Millepora* traversing the core, apparently in position of growth. A microscopic section shows that the structure has been replaced by crystalline dolomitic limestone, and the original interspaces are now filled with fine sediment. Alcyonarian spicules. The larger part of the core consists of foraminifera and fragmental materials. The former belong to *Miliolina*, *Orbitolites*, *Carpenteria*, *Calcarina*, *Gypsina inhærens*, *Polytrema miniaceum*, *P. planum*, *Amphistegina*, and *Heterostegina*. Echinid spines. Casts of gastropods and lamellibranchs. *Cliona* borings. Calcisponge spicule. *Lithothamnion*.

(704A). Length 370 millims. Whitish, hard, minutely porous. Only one or two pieces of perforate coral, (?) *Madrepora*. Thick laminæ of *Millepora*, in position of growth, extending obliquely through one half of the core. *Lobophytum* and detached alcyonarian spicules. Thick encrusting layers of *Polytrema planum*. *Orbitolites*, *Carpenteria*, and *Amphistegina*. Echinid spines. Casts of lamellibranchs and gastropods. *Cliona* borings. *Lithothamnion*. Foraminifera and fragmental materials are predominant in this core like as in the preceding.

(705A, 706A) [833]. Length 228 millims. Rock like the preceding. A few corals present; casts of *Pocillopora*, simple Astræan, genus undetermined, *Madrepora* and *Porites*. Alcyonarian spicules. The larger part of the cores consists of foraminifera and detrital materials. The most abundant forms belong to *Orbitolites*, *Polytrema*, and *Amphistegina*, and the less prominent to *Miliolina*, *Textularia rugosa*, *Carpenteria*, *Gypsina inhærens*, *G. discus*, and *Heterostegina*. Echinid spines. Casts of gastropods. *Cliona* borings.

(707A) [834]. Length 148 millims. Whitish, hard, minutely porous dolomitic limestone, with occasional hollows. The core consists chiefly of a number of small corals, together with foraminifera and detrital sediment. Casts of *Pocillopora* and *Madrepora*. *Millepora*, *Lobophytum*, and detached alcyonarian spicules. The corals are overgrown by *Polytrema planum* and by *Lithothamnion*. *Orbitolites*, *Carpenteria*, *Calcarina*, and *Amphistegina*. Echinid spines. Casts of gastropods.

(708A). Length 175 millims. Whitish, hard, minutely porous, with occasional hollows. Small forms of *Stylophora*, *Pocillopora*, simple Astræan and *Madrepora* overgrown by *Polytrema*, are fairly numerous in the upper part of the core, whilst the lower half principally consists of foraminifera belonging to *Orbitolites*, *Amphistegina*, and *Heterostegina*. Echinid spines. Casts of gastropods and lamellibranchs. *Cliona* borings.

(709A) [603]. Length 85 millims. Whitish, hard, minutely porous, dolomitic limestone, like the preceding. With the exception of one or two casts of small undetermined corals, which are enclosed by *Polytrema planum*, the core is composed of foraminifera and detrital material cemented by crystalline dolomite. Echinid spines. *Orbitolites*, *Textularia*, *Carpenteria*, *Gypsina inhærens*, and *Amphistegina*. Branching *Lithothamnion*.

(4) Notes on the Cores from the First Boring "C" (Sollas, 105 Feet).

A general description of the structure of the rock passed through in the first boring was given by Professor W. J. Sollas in his report to the Royal Society,* from which it appears that the site was near the sandy beach of the lagoon, less than ½ mile to the south-west of the village of Funafuti. The boring was carried down to a depth of 105 feet, through sand, coral reefs, and blocks, and its further extension was prevented by an influx of "sand."

The total length of the solid cores obtained was 7⅓ feet, or about 7 per cent.

* 'Roy. Soc. Proc.,' vol. 60, No. 367, March, 1897, p. 503. See also Section I, *supra*.

greenish. *Heliopora cærulea*, encrusted in places by *Polytrema planum*. *Orbitolites*, *Serpula*-tubes, small gastropods, branching and nodose *Lithothamnion*.

(C. 4) [301]. Length 40 millims., width 45 millims. An irregular piece of cream-coloured limestone, with *Heliopora* and *Lithothamnion*. Fragmental materials, partly consolidated, partly as soft white powder, with *Nubecularia*, *Miliolina*, *Orbitolites*, *Placopsilina*, *Gypsina inhærens*, *Polytrema planum* and *Amphistegina*. Echinid spines, *Serpula*-tubes, *Leptoclinum* stellates, small gastropods, and coprolitic pellets.

(C. 5). Length 16 millims., by 56 millims. in width. An irregular fragment of *Heliopora*, with encrusting *Lithothamnion*.

(C. 5_1) [316]. Length 32 millims., width 47 millims. An irregular, cavernous piece of branching *Lithothamnion*, with partly cemented sedimentary material containing *Orbitolites*, *Haddonia*, and *Polytrema*. Echinid spines, *Serpula*, *Leptoclinum* stellates, and small gastropods.

Depth from Surface, 30–50 *feet*; *Distance Bored*, 20 *feet*; *Total Length of Core Obtained*, 2 *feet* 3 *inches*; *Numbers of Cores*, C. 6–C. 15.

The cores are partly cylindrical and very cavernous, partly irregular fragments of cream-coloured, greyish-white and greenish limestone. They principally consist of corals, masses of *Heliopora cærulea* being the commonest form, *Orbicella*, *Psammocora*, and *Montipora*. The corals are in part embedded in a fine, hard sediment containing *Nubecularia*, *Miliolina*, *Orbitolites*, *Valvulina*, *Planorbulina*, *Carpenteria*, *Gypsina inhærens*, *Polytrema planum*, and *Amphistegina*. Also echinid spines, *Spirorbis*, *Leptoclinum* stellates, detached calcisponge spicules; infilled *Cliona* borings and *Lithothamnion*.

DETAILS.

(C. 6) [302]. Length 23 millims., width 53 millims. A fragment of greyish, porous limestone, composed of foraminifera and detrital organic materials, cemented by "conchite," or aragonite. Fragments of coral structure, *Miliolina*, *Orbitolites*, *Carpenteria*, *Gypsina*, *Polytrema planum* and *Amphistegina*. Echinid plates and spines, *Leptoclinum* stellates, surrounded by minute pellets of calcareous mud, fragments of *Lithothamnion*.

(C. 7) [304]. Length 16 millims. A piece of *Heliopora cærulea*, encrusted by alternating layers of *Polytrema planum* and *Lithothamnion*, and embedded in consolidated sediment with *Leptoclinum* stellates. *Carpenteria* (?). *Cliona* borings infilled with fine sediment. Spicule of calcisponge.

(C. 8). Length 36 millims., width 62 millims. An irregular nodule of greyish rock, showing within a dull greenish tint. Mainly a mass of *Heliopora cærulea*, with *Polytrema planum* and echinid spines.

(C. 9) [323]. Length 128 millims., width 70 millims. Part of cylindrical core of cream-coloured limestone, very cavernous, mostly hard, but with unconsolidated, powdery material in some of the cavities. The rock mainly of *Heliopora cærulea*, with a laminate coral of uncertain character, encrusted by *Polytrema* and *Lithothamnion*. Dense, hardened sediment, with *Nubecularia*, *Planorbulina*, *Carpenteria*, and *Gypsina inhærens*. *Leptoclinum* stellates. Calcisponge spicule.

(C. 10) [324]. Length 123 millims., width 79 millims. Cylindrical core, very cavernous, greyish on the exterior, partly white, partly greenish in section. Rock similar to preceding; a large mass of *Heliopora*, also specimen of *Orbicella*, encrusted by *Polytrema planum* and by *Lithothamnion*. In the hardened sediment *Orbitolites*, *Valvulina*, and *Gypsina*. Echinid spines, small gastropods, *Leptoclinum* stellates.

(C. 11). Length 25 millims., width 44 millims. A fragment of whitish-grey, hard, porous rock, composed of undetermined coral, *Orbitolites*, echinid spines, *Halimeda* and *Lithothamnion*.

(C. 12) [325]. Length 117 millims., width 81 millims. Core cylindrical, greyish-white, with green

Of the loose material or "sand," which is such an important constituent of this boring, there were samples taken at no great depth from the surface and also near the bottom of the boring, at 90 feet. These consisted principally of foraminifera, which in the sample from near the surface appear to be essentially the same forms as those of the beach, and may have been in part derived from the beach. From the other sample, and in the sedimentary materials associated with the solid cores, the following genera of foraminifera were determined by Mr. CHAPMAN: *Nubecularia*, *Miliolina*, *Orbitolites*, *Placopsilina*, *Haddonia*, *Textularia*, *Verneuilina*, *Discorbina*, *Planorbulina*, *Truncatulina*, *Carpenteria*, *Pulvinulina*, *Calcarina*, *Amphistegina* and *Heterostegina*.

Other organisms in the incoherent materials include detached spicules of calcisponges, echinid spines, a single small *Cidaris*, *Serpula* tubes, *Spirorbis*, stellate *Leptoclinum* spicules, Cheilostomatous polyzoa, small gastropods belonging to *Ringicula* and *Diala*; *Lithodomus*, *Halimeda* joints and small coprolitic pellets.

Depth from Surface, 0–30 *feet; Distance Bored*, 30 *feet; Total Length of Core Obtained*, 8 *inches; Numbers of Cores*, C. 1–C. 5_1.

The solid rock-cores from this part of the boring consist of irregular fragments of cream-coloured, whitish, and dirty greenish limestone, hard, porous, and in places very cavernous. There is also a sample of loose, powdery material, chiefly of foraminifera, from no great depth from the surface, but as these are of the same character as the beach deposits of the locality, and probably are, to some extent, derived from them, I have not included them as part of the core material.

The rock-cores are mainly composed of *Heliopora cærulea*, *Orbicella*, and branching *Lithothamnion*. The hollows between the corals and calcareous algæ are partly filled with foraminifera and sedimentary materials, either unconsolidated or cemented with fibrous crystals of "conchite," or aragonite. The foraminifera belong to *Nubecularia*, *Miliolina*, *Orbitolites*, *Placopsilina*, *Haddonia*, *Carpenteria*, *Gypsina inhærens*, *Polytrema planum*, and *Amphistegina Lessonii*. Other organic remains are echinid spines, *Serpula*-tubes, Cheilostomatous polyzoa, diminutive gastropods, determined by Mr. EDGAR SMITH to belong to *Ringicula* and *Diala*, detached stellate spicules of *Leptoclinum*, joints of *Halimeda* and small coprolitic pellets.

DETAILS.

(C. 1). Length 45 millims., width 75 millims. An irregular, cavernous nodule of whitish-grey limestone, hard, consisting principally of *Heliopora*, *Orbicella*, and branching *Lithothamnion*. Echinid spines, *Serpula*, polyzoa, small gastropods, joints of *Halimeda*.

(C. 2). Length 35 millims., width 75 millims. Partly cylindrical, greyish, hard limestone; cavernous. *Heliopora*, with nodular and branching *Lithothamnion*. In places, powdery material, with *Orbitolites* and *Amphistegina*. *Polytrema planum*. Echinid spines, *Serpula*, gastropods, and *Halimeda*.

(C. 3). Length 35 millims., width 68 millims. An irregular fragment, partly greyish-white, partly

(C. 21). Length 22 millims. A fragment of grey-greenish limestone, with *Heliopora*, and a perforate coral. *Polytrema*, *Amphistegina*, and *Lithothamnion*.

(C. 22) [317]. Length 40 millims., width 80 millims. Cylindrical core, cavernous. Composed of a group of small *Fungia* (?), with perforate coral, *Heliopora cærulea*, and fragmentary material. *Orbitolites*, *Planorbulina*, *Polytrema planum*, and *Amphistegina*. *Leptoclinum* stellates. *Halimeda*, abundant, *Lithothamnion*.

Depth from Surface, 80–85 *feet*; *Distance Bored*, 5 *feet*; *Total Length of Core Obtained*, 1 *foot* 1 *inch*; *Numbers of Cores*, C. 23–C. 28.

The cores are partly cylindrical, partly mere fragments of whitish-grey, hard, compact limestones, composed mainly of corals aggregated together. The corals are very obscurely shown, owing to their interspaces being infilled with fibrous crystals or with fine sediment. The corals belong to *Pocillopora*, *Astræa* (?), *Orbicella*, *Porites* (?), and *Montipora*. *Millepora* is also present. The foraminifera are represented by *Nonionina* (?), *Orbitolites*, *Gypsina*, and *Polytrema*. *Serpula*, *Spirorbis*, *Lithodomus*, boring in corals. *Lithothamnion*. *Cliona* borings.

DETAILS.

(C. 23) [312]. Length 75 millims., width 77 millims. Part of cylindrical core of compact greyish limestone. Mainly of corals; an Astræan and *Montipora*, which are encrusted by *Polytrema planum* and *Lithothamnion*. *Orbitolites marginalis*, *Gypsina inhærens*, and *Nonionina* (?). *Serpula*, *Spirorbis*.

(C. 24) [318]. Length 41 millims. A fragment of hard limestone, mostly white, but in places stained reddish. Consists of *Pocillopora*, bored by *Cliona*. The structure of the coral preserved, the interspaces mostly filled up solid with sclerenchyma or with fibrous crystals, and occasionally with sediment, containing *Carpenteria*, and *Leptoclinum* spicules. *Spirorbis*. Encrusting *Lithothamnion*.

(C. 25). Length 20 millims. A fragment of *Millepora*, the pores infilled with matrix. Encrusted by *Polytrema planum*. *Spirorbis*.

(C. 26). Length 46 millims., width 66 millims. An irregular nodule of whitish-grey limestone, partly compact, partly porous, consisting of a perforate coral, encrusted by *Polytrema* and *Lithothamnion*. *Serpula*.

(C. 27). Length 25 millims. A fragment of limestone similar to the preceding, with perforate coral, bored by *Cliona*. *Polytrema miniaceum*. Echinid spines. *Serpula*-tubes.

(C. 28) [313, 319]. Length 111 millims., diameter 80 millims. Core cylindrical, with a large hollow. Principally a mass of corals; *Astræa*, *Orbicella*, and *Montipora*. Corals encrusted by *Lithothamnion*. *Lithodomus* borings in *Montipora*. *Serpula*. *Gypsina inhærens*. Outer surface of rock covered with small pits, and minute *Spirorbis* attached.

Depth from Surface, 85–105 *feet*; *Distance Bored*, 20 *feet*; *Total Length of Core Obtained*, 1 *foot* 11 *inches*; *Numbers of Cores*, C. 29–C. 36.

Cylindrical cores and irregular nodular lumps of hard cream-tinted limestone, with occasional greenish patches where *Heliopora* is present. Also a sample of loose materials, brought up by the sand-pump from a depth of 90 feet. The solid cores are almost entirely of corals in fairly good preservation. They belong to the

following genera :—*Stylophora*, *Orbicella*, *Madrepora*, *Montipora*, *Heliopora cærulea* and alcyonarian spicules. The foraminifera recognised by Mr. CHAPMAN, chiefly in the sample of loose materials, are *Miliolina*, *Orbitolites*, *Textularia*, *Verneuilina*, *Truncatulina*, *Carpenteria*, *Pulvinulina*, *Calcarina*, *Gypsina*, *Amphistegina* and *Heterostegina*.

There are also present echinid spines, *Serpula*, *Spirorbis*, polyzoa, *Leptoclinum* stellates, small lamellibranchs and gastropods, ovoid coprolitic pellets, fragments of encrusting *Lithothamnion* and *Halimeda*.

DETAILS.

(C. 29) [315]. Length 75 millims., width 79 millims. Cylindrical core, of hard cream-coloured limestone. The surface pitted in places and with *Spirorbis* attached. Entirely of corals, mainly *Montipora*, with pieces of *Stylophora*, *Madrepora* and *Heliopora cærulea*. A microscopic section of this latter shows the minute structure as distinctly as in recent specimens. *Serpula*, polyzoa, *Leptoclinum* stellates and *Lithothamnion* encrusting corals.

(C. 30). Length 80 millims., width 73 millims. An irregular fragment consisting of a mass of *Heliopora cærulea*; in the central portion the corallites are empty, the outer ones are filled up, partly with sediment. The coral covered in places with white, hard, consolidated sediment.

(C. 31) [314]. Length 67 millims., width 77 millims. Part of a cylindrical core of hard compact limestone, mainly of *Montipora*, with a fragment of *Orbicella*. Outer surface of core pitted in places. *Orbitolites*, *Amphistegina*. Encrusting *Lithothamnion*. *Cliona* borings.

(C. 32). Length 60 millims., width 52 millims. A rounded nodule of cream-tinted, hard limestone, worn by the drill. It consists of *Orbicella*, cf. *O. orion*, DANA, in good preservation.

(C. 33). Length 44 millims., width 46 millims. A nodule of hard, greyish-white, compact limestone, showing in some parts a pitted surface with *Spirorbis* attached. The core consists of *Montipora*, sp., similar to that in C. 31.

(C. 34) [322]. Length 47 millims., width 77 millims. An irregular nodule, worn by drill, of hard limestone, consisting of *Orbicella*, cf. *O. orion*, the same as in C. 32. The coral structure well shown in the microscopic section. Encrusting *Lithothamnion*.

(C. 35) [320]. Length 131 millims., width 74 millims. A portion of a cylindrical core of compact limestone, with about half the surface pitted and *Spirorbis* growing on it. The core consists of a mass of the same *Orbicella* as the preceding, with a small *Montipora* growing on it. Encrusting *Lithothamnion* in very thin undulating laminæ.

(C. 36) [321]. Length 80 millims., width 75 millims. An irregular nodule of the same *Orbicella* as in the two preceding cores. *Spirorbis*, Cheilostomatous polyzoa, *Leptoclinum* stellates, encrusting *Lithothamnion*.

Sample of loose materials, from a depth of 90 feet, consisting of small subangular particles of broken up whitish limestone, with numerous foraminifera and other organisms. The genera most frequently represented are *Orbitolites*, *Amphistegina* and *Heterostegina*; other genera of less common occurrence are *Miliolina*, *Textularia*, *Verneuilina*, *Truncatulina*, *Carpenteria*, *Pulvinulina*, *Calcarina* and *Gypsina*. Broken fragments of perforate corals are also present, together with alcyonarian spicules, echinid spines, polyzoa, small molluscan shells, fragments of *Halimeda*, and numerous small coprolitic ovoid pellets. Microscopic sections of some of these pellets show that they are composed of minute fragments of foraminifera, corals, stellate ascidian spicules, *Lithothamnion*, and other particles of organisms, closely packed together.

(C. 21). Length 22 millims. A fragment of grey-greenish limestone, with *Heliopora*, and a perforate coral. *Polytrema*, *Amphistegina*, and *Lithothamnion*.

(C. 22) [317]. Length 40 millims., width 80 millims. Cylindrical core, cavernous. Composed of a group of small *Fungia* (?), with perforate coral, *Heliopora cærulea*, and fragmentary material. *Orbitolites*, *Planorbulina*, *Polytrema planum*, and *Amphistegina*. *Leptoclinum* stellates. *Halimeda*, abundant, *Lithothamnion*.

Depth from Surface, 80–85 *feet*; *Distance Bored*, 5 *feet*; *Total Length of Core Obtained*, 1 *foot* 1 *inch*; *Numbers of Cores*, C. 23–C. 28.

The cores are partly cylindrical, partly mere fragments of whitish-grey, hard, compact limestones, composed mainly of corals aggregated together. The corals are very obscurely shown, owing to their interspaces being infilled with fibrous crystals or with fine sediment. The corals belong to *Pocillopora*, *Astræa* (?), *Orbicella*, *Porites* (?), and *Montipora*. *Millepora* is also present. The foraminifera are represented by *Nonionina* (?), *Orbitolites*, *Gypsina*, and *Polytrema*. *Serpula*, *Spirorbis*, *Lithodomus*, boring in corals. *Lithothamnion*. *Cliona* borings.

DETAILS.

(C. 23) [312]. Length 75 millims., width 77 millims. Part of cylindrical core of compact greyish limestone. Mainly of corals; an Astræan and *Montipora*, which are encrusted by *Polytrema planum* and *Lithothamnion*. *Orbitolites marginalis*, *Gypsina inhærens*, and *Nonionina* (?). *Serpula*, *Spirorbis*.

(C. 24) [318]. Length 41 millims. A fragment of hard limestone, mostly white, but in places stained reddish. Consists of *Pocillopora*, bored by *Cliona*. The structure of the coral preserved, the interspaces mostly filled up solid with sclerenchyma or with fibrous crystals, and occasionally with sediment, containing *Carpenteria*, and *Leptoclinum* spicules. *Spirorbis*. Encrusting *Lithothamnion*.

(C. 25). Length 20 millims. A fragment of *Millepora*, the pores infilled with matrix. Encrusted by *Polytrema planum*. *Spirorbis*.

(C. 26). Length 46 millims., width 66 millims. An irregular nodule of whitish-grey limestone, partly compact, partly porous, consisting of a perforate coral, encrusted by *Polytrema* and *Lithothamnion*. *Serpula*.

(C. 27). Length 25 millims. A fragment of limestone similar to the preceding, with perforate coral, bored by *Cliona*. *Polytrema miniaceum*. Echinid spines. *Serpula*-tubes.

(C. 28) [313, 319]. Length 111 millims., diameter 80 millims. Core cylindrical, with a large hollow. Principally a mass of corals; *Astræa*, *Orbicella*, and *Montipora*. Corals encrusted by *Lithothamnion*. *Lithodomus* borings in *Montipora*. *Serpula*. *Gypsina inhærens*. Outer surface of rock covered with small pits, and minute *Spirorbis* attached.

Depth from Surface, 85–105 *feet*; *Distance Bored*, 20 *feet*; *Total Length of Core Obtained*, 1 *foot* 11 *inches*; *Numbers of Cores*, C. 29–C. 36.

Cylindrical cores and irregular nodular lumps of hard cream-tinted limestone, with occasional greenish patches where *Heliopora* is present. Also a sample of loose materials, brought up by the sand-pump from a depth of 90 feet. The solid cores are almost entirely of corals in fairly good preservation. They belong to the

following genera :—*Stylophora*, *Orbicella*, *Madrepora*, *Montipora*, *Heliopora cærulea* and alcyonarian spicules. The foraminifera recognised by Mr. CHAPMAN, chiefly in the sample of loose materials, are *Miliolina*, *Orbitolites*, *Textularia*, *Verneuilina*, *Truncatulina*, *Carpenteria*, *Pulvinulina*, *Calcarina*, *Gypsina*, *Amphistegina* and *Heterostegina*.

There are also present echinid spines, *Serpula*, *Spirorbis*, polyzoa, *Leptoclinum* stellates, small lamellibranchs and gastropods, ovoid coprolitic pellets, fragments of encrusting *Lithothamnion* and *Halimeda*.

DETAILS.

(C. 29) [315]. Length 75 millims., width 79 millims. Cylindrical core, of hard cream-coloured limestone. The surface pitted in places and with *Spirorbis* attached. Entirely of corals, mainly *Montipora*, with pieces of *Stylophora*, *Madrepora* and *Heliopora cærulea*. A microscopic section of this latter shows the minute structure as distinctly as in recent specimens. *Serpula*, polyzoa, *Leptoclinum* stellates and *Lithothamnion* encrusting corals.

(C. 30). Length 80 millims., width 73 millims. An irregular fragment consisting of a mass of *Heliopora cærulea*; in the central portion the corallites are empty, the outer ones are filled up, partly with sediment. The coral covered in places with white, hard, consolidated sediment.

(C. 31) [314]. Length 67 millims., width 77 millims. Part of a cylindrical core of hard compact limestone, mainly of *Montipora*, with a fragment of *Orbicella*. Outer surface of core pitted in places. *Orbitolites*, *Amphistegina*. Encrusting *Lithothamnion*. *Cliona* borings.

(C. 32). Length 60 millims., width 52 millims. A rounded nodule of cream-tinted, hard limestone, worn by the drill. It consists of *Orbicella*, cf. *O. orion*, DANA, in good preservation.

(C. 33). Length 44 millims., width 46 millims. A nodule of hard, greyish-white, compact limestone, showing in some parts a pitted surface with *Spirorbis* attached. The core consists of *Montipora*, sp., similar to that in C. 31.

(C. 34) [322]. Length 47 millims., width 77 millims. An irregular nodule, worn by drill, of hard limestone, consisting of *Orbicella*, cf. *O. orion*, the same as in C. 32. The coral structure well shown in the microscopic section. Encrusting *Lithothamnion*.

(C. 35) [320]. Length 131 millims., width 74 millims. A portion of a cylindrical core of compact limestone, with about half the surface pitted and *Spirorbis* growing on it. The core consists of a mass of the same *Orbicella* as the preceding, with a small *Montipora* growing on it. Encrusting *Lithothamnion* in very thin undulating laminæ.

(C. 36) [321]. Length 80 millims., width 75 millims. An irregular nodule of the same *Orbicella* as in the two preceding cores. *Spirorbis*, Cheilostomatous polyzoa, *Leptoclinum* stellates, encrusting *Lithothamnion*.

Sample of loose materials, from a depth of 90 feet, consisting of small subangular particles of broken up whitish limestone, with numerous foraminifera and other organisms. The genera most frequently represented are *Orbitolites*, *Amphistegina* and *Heterostegina*; other genera of less common occurrence are *Miliolina*, *Textularia*, *Verneuilina*, *Truncatulina*, *Carpenteria*, *Pulvinulina*, *Calcarina* and *Gypsina*. Broken fragments of perforate corals are also present, together with alcyonarian spicules, echinid spines, polyzoa, small molluscan shells, fragments of *Halimeda*, and numerous small coprolitic ovoid pellets. Microscopic sections of some of these pellets show that they are composed of minute fragments of foraminifera, corals, stellate ascidian spicules, *Lithothamnion*, and other particles of organisms, closely packed together.

(5) Notes on the Cores from the Second Boring "D" (Sollas, 72 Feet).

The second boring (D), undertaken by Professor SOLLAS in 1896, was situated further to the south of the Mission Church than the first, and on the ocean side of the reef.* The bore-hole was carried down to a depth of 72 feet from the surface, when it became choked with *débris* and had to be abandoned. No samples of the† rock between the surface and 12 feet below appear to have been brought to England; between 12 feet and the bottom of the boring, 72 feet, the length of the solid cores obtained was 12 feet 5 inches, which would average a little over 1 foot of solid core in each 5 feet of the actual boring. The distribution of the cores in various parts of the boring is shown in the following table:—

Depth from surface in feet.	Distance bored in feet.	Length of cores.	Numbers of cores.
		ft. in.	
0–12	12	...	—
12–20	8	1 4	D. 1–D. 4
20–30	10	0 10	D. 5–D. 10
30–40	10	1 2	D. 11–D. 17
40–50	10	3 0	D. 18–D. 35
50–60	10	3 7	D. 36–D. 57
60–72	12	2 6	D. 58–D. 74
	72	12 5	

Some of the cores are cylindrical with the same maximum diameter as those of the First Boring (C), viz., 3¼ inches (80 millims.), but the larger number are fragments of cores, often rounded into nodules by the drill, or irregular in shape. The cores further resemble those of the First Boring in having their surfaces covered in places with small shallow pits, probably the work of boring organisms, and in these pits colonies of a small species of *Spirorbis* have become attached.

The character of the rock forming the cores is very uniform throughout the boring. It is a cream-coloured or greyish-white hard limestone, generally compact, but occasionally porous where the interstices of corals have remained empty.

To a very large extent the solid cores are composed of corals which retain their form and structure throughout, but their characters are often very much obscured by the way in which the interseptal and intercostal spaces, and the pores in the perforate forms, are now solidly infilled with sclerenchyma or with crystalline fibrous material, so similar to that of the coral tissues, that these latter can hardly be distinguished unless in microscopic sections. The prevailing coral which forms the larger part of nearly every core is *Madrepora*, and probably it is represented by the single

* See Section I, *supra*.

† Professor SOLLAS states that a pit was sunk from the surface to a depth of 11 feet through fragments of coral, crystalline coral limestone, and partly consolidated sand (see p. 4, *supra*).

species *M. contecta*. Other corals occurring with the *Madrepora* are *Pocillopora*, rare, *Astræa* (?) *Orbicella*, *Montipora*, *Porites*, and an undetermined form. A few examples of *Millepora* occur, and a single small specimen of *Heliopora cærulea* was noticed, also detached spicules of alcyonaria.

The corals are usually perforated to a varying extent by the borings of *Cliona* sponges and other organisms, which are generally infilled with fine consolidated sediment or with crystalline fibrous "conchite" or aragonite. The infilling sediment contains numerous detached ascidian stellate spicules referred to *Leptoclinum*. No traces of the siliceous spicules of the boring *Cliona* have been found in any of the microscopic sections of the cores.

If we except *Polytrema planum*, which, with *Lithothamnion*, is generally present encrusting the corals, foraminifera are not of common occurrence in connection with the solid cores, and they are limited to a few examples of *Orbitolites*, *Spirillina*, *Carpenteria*, *Calcarina*, *Gypsina inhærens*, *Polytrema miniaceum* and *Amphistegina*, but in samples of unconsolidated material from depths of 40 and 70 feet, foraminifera are very abundant, and many additional genera, the names of which are given below, have been recognised.

Of other organisms not already mentioned, there are in the solid cores and in the loose material, detailed calcisponge spicules, echinid spines, *Serpula*, *Spirorbis*, claws of crustacea, entomostraca, stellate ascidian spicules, lamellibranchs and gastropods, small coprolitic pellets, joints of corallines and of *Halimeda*.

The solid cores from this Second Boring are generally similar to those of the First and also to those of the corresponding depth in the Main Boring in being composed mainly of corals, but whilst the predominant form in the Second Boring is *Madrepora contecta* and *Heliopora cærulea* is of rare occurrence, the reverse happens in the First Boring (C), where *Heliopora* is extremely abundant, and only in one instance has *Madrepora* been noticed. In the Main Boring, on the other hand, *Heliopora* forms a marked feature in the upper part, whilst below the level of 40 feet from the surface *Madrepora contecta* largely predominates.

Foraminifera and other small organisms appear as a rule not to have been consolidated into hard rock in the First and Second Borings, or in the upper part of the Main Boring, and they form but a small part of the solid cores, but they are extremely abundant in the loose, incoherent materials obtained at various depths from these borings.

Depth from Surface, 0–12 feet; No Cores Obtained.

According to Professor SOLLAS the rock for a depth of 11 feet from the surface consisted of fragments of coral, crystalline coral limestone, and partly consolidated sand.

Depth from Surface, 12–20 feet; Distance Bored, 8 feet; Total Length of Core Obtained, 1 foot 4 inches; Numbers of Cores, D. 1–D. 4.

Cores cylindrical and nodular, very cavernous, of cream-tinted and whitish-grey, hard limestones, compact to minutely porous. Mainly of corals: the most abundant form is *Madrepora contecta*, associated with it are *Orbicella*, *Montipora*, and *Porites*. Corals encrusted by *Lithothamnion*. Coarse consolidated sedimentary material in some of the spaces between the corals contains *Carpenteria*, *Calcarina*, *Polytrema*, and *Amphistegina*; also echinid spines, and small gastropods. *Serpula*, Cheilostomatous polyzoa, *Cliona* borings.

DETAILS.

(D. 1) [401]. Length 67 millims., width 69 millims. An irregular nodule of cream-coloured limestone principally of *Madrepora contecta*. The pores in the coral sometimes hollow or filled up with crystalline fibres or with sediment. *Polytrema miniaceum*. *Lithothamnion*.

(D. 2) [416, 419]. Length 152 millims., width 80 millims. Cylindrical core of greyish-white hard rock, very cavernous. Consisting chiefly of corals with some coarse sedimentary material. Small *Orbicella* (?), a large mass of *Madrepora contecta* and *Montipora*. *Carpenteria*, *Calcarina*, *Amphistegina*. Echinid spines. Cheilostomatous polyzoa. Thick layers of *Lithothamnion* encrusting corals. *Serpula*. In sedimentary material, numerous *Leptoclinum* stellates.

(D. 3). Length 90 millims., width 80 millims. Cylindrical core, cavernous, of rock similar to preceding. Consisting of *Madrepora contecta* and *Montipora*, with a thick intervening layer of *Lithothamnion*. *Serpula*. Echinid spines. *Polytrema miniaceum*.

(D. 4) [417]. Length 85 millims., width 56 millims. A nodular mass, rounded by drill, of greyish-white limestone, composed of *Madrepora contecta*, encrusted by *Lithothamnion*. Echinid spines. *Cliona* borings. Branching *Lithothamnion*.

Depth from Surface, 20–30 feet; Distance Bored, 10 feet; Total Length of Core Obtained, 10 inches; Numbers of Cores, D. 5–D. 10.

Cores of greyish-white hard limestone, mostly in nodular masses. Nearly altogether of the same *Madrepora contecta* as the previous cores, with *Orbicella*, *Montipora*, and an undetermined perforate coral. *Leptoclinum* stellates. *Cliona* borings. Joints of *Halimeda*.

DETAILS.

(D. 5, D. 6) [402, 420]. Length 75 millims., width 80 millims. Irregular nodules of limestone, consisting of *Madrepora contecta*. In part bored by *Cliona*. *Leptoclinum* stellates.

(D. 7) [421]. Length 60 millims., width 74 millims. Cylindrical core of greyish-white, compact to porous, limestone, nearly altogether of the *Madrepora contecta*. This is overgrown by *Lithothamnion*, and over this in turn a colony of *Orbicella* has spread itself.

(D. 8). Length 34 millims., width 73 millims. An irregular nodule of rock similar to the preceding, with *Madrepora contecta*, *Orbicella*, and *Montipora*. *Polytrema miniaceum*.

(D. 9) [422, 423]. Length 47 millims. A nodular fragment of the usual hard, whitish-grey rock, it is composed of a perforate coral of uncertain character, encrusted with *Lithothamnion*. Sedimentary material with *Leptoclinum* stellates and joints of *Halimeda*.

(D. 10). Length 30 millims., width 70 millims. A fragment of the same kind of rock as the preceding, composed of *Madrepora contecta*.

Depth from Surface, 30–40 feet; Distance Bored, 10 feet; Total Length of Core Obtained, 1 foot 2 inches; Numbers of Cores, D. 11–D. 17.

The cores, for the most part, are irregular nodular masses rounded by the drill, but occasionally they are cylindrical and cavernous. They consist of cream-coloured and greyish-white, hard, compact limestone, similar to the preceding, containing *Madrepora contecta* and *Millepora.* Unconsolidated materials from the level of 40 feet contain a great variety of foraminifera, which, with those from the solid cores, are referred by Mr. CHAPMAN to the following genera; *Spiroloculina, Miliolina, Cornuspira, Bolivina, Cristellaria, Sagrina, Spirillina, Patellina, Cymbalopora, Discorbina, Carpenteria, Pulvinulina, Calcarina, Tinoporus, Polytrema* and *Amphistegina.* The greater number of these genera are only represented by single specimens. There occur also detached calcisponge spicules, *Cliona* borings, alcyonarian spicules, echinid spines; *Serpula* and *Spirorbis*, claws of crustacea, entomostraca, polyzoa, small gastropods; coprolitic pellets, *Lithothamnion* and joints of corallines.

DETAILS.

(D. 11–D. 14). Four nodular lumps of compact limestone, with a total length of 171 millims., containing *Madrepora contecta*. The cœnenchymal interspaces in part empty, in part filled with sclerenchyma. *Cliona* borings.

(D. 15) [403]. Length 42 millims., width 54 millims. An irregular nodule of brownish-grey limestone, containing a branch of *Madrepora*, overgrown in the central portion by *Lithothamnion*, and this in turn by *Millepora*. Layers of *Polytrema planum* and *Lithothamnion* alternately encrust the *Millepora*. *Carpenteria*, Annelid tubes, *Leptoclinum*.

(D. 16). Length 28 millims., width 70 millims. A compressed nodule of rock similar to the preceding, with pitted surface and *Spirorbis* attached. *Millepora* bored by *Cliona* and encrusted by *Lithothamnion*, which again is overgrown by *Madrepora*. *Polytrema miniaceum* and *Serpula*.

(D. 17). Length 116 millims., width 80 millims. Cylindrical core of whitish-grey limestone, partly porous and with cavernous hollows. The greater part consists of *Madrepora*, very obscurely shown, and some *Millepora*. *Polytrema miniaceum*, *Serpula* and *Spirorbis*. Echinid spines, small gastropod, *Lithothamnion*.

Samples of unconsolidated, light-greyish material from a depth of 40 feet, consisting largely of small sub-angular fragments of broken-up limestone with detached foraminifera. The commonest form is *Amphistegina Lessonii*, the other genera present are enumerated above. There are also calcisponge spicules, alcyonarian spicules, echinid spines, claws of crustacea, polyzoa, entomostraca, coprolitic pellets, and joints of corallines.

Depth from Surface, 40–50 feet; Distance Bored, 10 feet; Total Length of Core Obtained, 3 feet; Numbers of Cores, D. 18–D. 35.

Cylindrical cores and nodular lumps, worn by drill, of cream-coloured and whitish-grey, hard limestone, cavernous in places. The outer surfaces frequently pitted and with attached *Spirorbis*. The greater part of the rock consists of *Madrepora*, with occasionally an Astræan coral, *Orbicella* (?), *Porites*, *Montipora*, and the same undetermined perforate, previously noticed in D. 9. There is also a single fragment

of *Heliopora cærulea* from a depth of 48 feet; the first time this coral has been met with in this boring. The corals are, as a rule, filled in with hard tissue and obscurely shown, they are bored by *Cliona*, the borings infilled with calcareous sediment. Foraminifera are not common in the cores; the genera recognised are *Orbitolites*, *Gypsina inhærens*, *Polytrema* and *Amphistegina*. Echinid spines. *Serpula*, *Leptoclinum* stellates. *Lithodomus*. *Lithothamnion*, encrusting corals.

Details.

(D 18). Length 51 millims., width 72 millims. Piece of a cylindrical core of hard, whitish limestone, principally of *Lithothamnion* with small *Serpula*-tubes. A narrow band of an Astræan coral, *Orbicella* (?), obscurely shown, is in the midst of the calcareous alga.

(D. 19). Length 26 millims., width 58 millims. A fragment of whitish-grey porous limestone consisting of *Porites*, with *Serpula*-tubes and bored by *Cliona*.

(D. 20). Length 50 millims., width 58 millims. A fragment of cream-coloured limestone, consisting of a piece of *Madrepora*, partly encrusted by *Lithothamnion*, *Spirorbis* on outer surface.

(D. 21) [405]. Length 58 millims., width 80 millims. Part of cylindrical core, cavernous, of greyish, hard, compact limestone, consisting chiefly of *Madrepora*, bored by *Cliona*, and overgrown by a thick layer of *Lithothamnion*. *Orbitolites*. *Serpula*-tubes.

(D. 22) [424]. Length 56 millims., width 80 millims. Cylindrical core composed of *Madrepora*, overgrown by *Lithothamnion*, similar to the preceding. The interspaces of the coral now filled up with crystalline fibrous material not distinguishable from that of the coral itself. *Polytrema miniaceum*, *P. planum*, *Amphistegina*, *Leptoclinum* stellates in the fine sediment which has infilled the *Cliona* borings.

(D. 23). Length 72 millims., width 80 millims. Cylindrical core, cavernous, of greyish, hard limestone. Incoherent detrital material filling some of the hollows. *Madrepora contecta* (?) riddled with *Cliona* and other borings. *Polytrema miniaceum*. Echinid spines.

(D. 24). Length 63 millims., width 67 millims. Nodule of hard cream-coloured limestone, rounded by drill, consisting of *Madrepora contecta*.

(D. 25) [404]. Length 50 millims., width 73 millims. Piece of cylindrical core with the inner surface pitted and covered with *Spirorbis*. *Madrepora*. *Amphistegina Lessonii*. *Leptoclinum* stellates.

(D. 26). Length 42 millims., width 65 millims. An irregular nodule of *Madrepora*, overgrown by *Lithothamnion* and this in turn by *Porites*.

(D. 27). Length 28 millims., width 40 millims. A fragment of grey rock, consisting of *Porites*.

(D. 28). Length 30 millims., width 70 millims. A cake-shaped nodule of grey, compact, hard limestone, probably of *Madrepora*, bored by *Cliona* and other organisms, and overgrown by *Lithothamnion*. The exterior surface of nodule pitted and with *Spirorbis* attached.

(D. 28_1) [415]. Length 23 millims., width 45 millims. An irregular, pitted nodule of grey hard limestone, consisting of a piece of *Madrepora*, encrusted by *Polytrema planum* and *Lithothamnion*, and growing on this latter a thin layer of *Heliopora cærulea*. *Leptoclinum* stellates.

(D. 29). Length 74 millims., width 72 millims. About half a cylindrical core, of cream-tinted hard limestone. The greater part is of *Madrepora*, very poorly preserved, and encrusted by *Polytrema planum* and *Lithothamnion*. Also a piece of *Orbicella* (?). *Spirorbis*.

(D. 30). Length 29 millims., width 43 millims. Rock like preceding. A fragment of *Madrepora contecta* (?).

(D. 31). Length 47 millims., width 77 millims. A depressed core of whitish-grey, hard limestone, consisting of a mass of *Madrepora contecta*, with encrusting *Lithothamnion*. *Polytrema miniaceum* and *P. planum*.

(D. 32) [406]. Length 70 millims., width 62 millims. Rock like preceding. Chiefly of *Madrepora*, with a fragment of *Montipora*. *Spirorbis*. *Lithothamnion*.

(D. 33). Length 45 millims., width 46 millims. A nodular fragment of *Madrepora*.

(D. 34) [425]. Length 12 millims., width 28 millims. A small irregular fragment of whitish-grey limestone, consisting of an undetermined coral (?) similar to that in D. 9. *Polytrema planum*. *Spirorbis*. *Lithothamnion*.

(D. 35) [407]. Length 82 millims., width 78 millims. Cylindrical core, greyish-white, compact, with large cavities. About one-half of the core consists of *Madrepora* encrusted by *Lithothamnion*, and on this latter *Montipora* is growing. Part of surface pitted, with *Spirorbis* attached.

Depth from Surface, 50–60 feet; Distance Bored, 10 feet; Total Length of Core Obtained, 3 feet 7 inches; Numbers of Cores, D. 36–D. 57.

Cylindrical cores and irregular nodules of cream-tinted or greyish, hard, mostly compact, limestone, similar to the preceding. The rock, for the most part, consists of *Madrepora* with *Montipora*, *Porites*, Astræan coral and *Millepora*. The corals are now generally infilled with crystalline fibrous material very similar to the actual coral structure, so that they are very obscurely shown. The corals are extensively bored by *Cliona* and other perforating organisms, and usually encrusted by *Polytrema planum* and *Lithothamnion*. Only a few foraminifera are seen in the microscopic sections, they belong to *Orbitolites*, *Carpenteria*, and *Gypsina inhærens*. *Spirorbis* is plentiful, attached to the outer pitted surfaces of the masses of coral. *Leptoclinum* stellates. *Halimeda*, rare.

DETAILS.

(D. 36). Length 118 millims., width 80 millims. An irregular mass of greyish, hard, compact limestone, with pitted outer surface. Half of the mass consists of *Madrepora*, and half of *Porites*, with a thin layer of *Lithothamnion* between them. *Spirorbis*.

(D. 37). Length 54 millims., width 78 millims. Cylindrical core of rock similar to preceding, very cavernous. It consists of *Madrepora*. Part of outer surface pitted, and with *Spirorbis* attached.

(D. 38). Length 54 millims., width 68 millims. About one-third of the cylindrical core present. It consists of *Porites*, now infilled with crystalline material and hardly recognisable.

(D. 39) [408]. Length 70 millims., width 68 millims. Cylindrical core of greyish, hard, compact rock. Greater part of *Madrepora*, encrusted by *Lithothamnion* on which *Porites* has grown. Pitted surface with *Spirorbis*. *Orbitolites*, *Leptoclinum* stellates. *Halimeda*.

(D. 40). Length 16 millims., width 34 millims. An irregular fragment of whitish limestone, consisting of *Millepora* in immediate contact with *Madrepora*.

(D. 41). Length 25 millims., width 60 millims. A compressed nodule of rock of the same character and with the same organisms as the preceding.

(D. 42). Length 18 millims., width 28 millims. A fragment of limestone with *Madrepora* (?).

(D. 43). Length 42 millims., width 47 millims. A rounded nodule worn by the drill, of greyish, hard, very dense, limestone, consisting of *Madrepora*.

(D. 44). Length 80 millims., width 82 millims. Core cylindrical, about two-thirds preserved, of the same limestone as preceding. The rock is entirely of *Madrepora*.

(D. 45) [409]. Length 30 millims., width 73 millims. An irregular flattened nodule of cream-coloured limestone, composed of *Madrepora contecta*, much bored by *Cliona* and other organisms, and

encrusted by layers of *Polytrema planum* and *Lithothamnion*. Surface in places pitted, with *Spirorbis* attached.

(D. 46–D. 50). Total length 112 millims., width about 70 millims. Four irregular pieces of greyish-white, hard, limestone, consisting of *Madrepora* with *Cliona* borings.

(D. 51) [426]. Length 75 millims., width 80 millims. Greyish-white limestone, consisting of a mass of *Montipora* (?), encrusted by *Polytrema planum* and *Lithothamnion*. *Orbitolites* and *Gypsina inhaerens*.

(D. 52). Length 47 millims., width 79 millims. Cylindrical core of *Montipora* (?) similar to the preceding.

(D. 53, D. 54). Total length 109 millims., width 80 millims. Cylindrical cores of greyish-white, hard limestone, consisting of *Madrepora contecta*, perforated by *Cliona*.

(D. 55). Length 40 millims., width 58 millims. An irregular fragment of *Madrepora contecta*.

(D. 56). Length 62 millims., width 83 millims. Cylindrical cores, cavernous, of the usual greyish-white dense limestone, composed of *Montipora* (?), bored by *Cliona*, and encrusted by *Lithothamnion*.

(D. 57) [410]. Length 74 millims., width 75 millims. Cylindrical core, cavernous, of greyish-white, hard, mostly compact, limestone, the surface in places pitted, and with *Spirorbis* attached. *Madrepora contecta* (?), encrusted by *Lithothamnion* and overgrown by *Montipora* (?), very obscurely shown, and this in turn covered by layers of *Polytrema planum* and *Lithothamnion*. *Orbitolites*, *Polytrema miniaceum*. Echinid spines.

Depth from Surface, 60–72 *feet; Distance Bored*, 12 *feet; Total Length of Cores Obtained*, 2 *feet* 6 *inches; Numbers of Cores*, D. 58–D. 74.

Cylindrical cores, and irregular nodules of cream-coloured and whitish-grey, hard, mostly compact limestone, of the same character as those from the higher parts of the boring. The greater part of the rock consists of corals, *Madrepora contecta* being still the predominant form; with it there are associated *Pocillopora*, *Orbicella* (?), *Montipora*, and detached alcyonarian spicules. Corals, generally filled up solid with sclerenchyma, &c., and very obscurely shown. Foraminifera are seldom met with in the cores, but in a sample of unconsolidated material from a depth of 70 feet they are abundant and varied. The following genera have been recognised by Mr. CHAPMAN: *Cornuspira*, *Orbitolites*, *Sagrina*, *Globigerina*, *Pullenia*, *Spirillina*, *Discorbina*, *Planorbulina*, *Pulvinulina*, *Calcarina*, *Tinoporus*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Associated with these there are calcisponge spicules, *Cliona* borings, echinid spines, *Serpula*, and *Spirorbis*, ostracoda, lamellibranchs, and encrusting *Lithothamnion*.

DETAILS.

(D. 58). Length 50 millims., width 80 millims. Core of whitish-grey, compact limestone, both upper and lower faces pitted. Nearly the entire core of *Madrepora contecta* (?); a small fragment of *Montipora*. *Polytrema miniaceum*. *Cliona* borings. *Lithothamnion*.

(D. 59). Length 74 millims., width 77 millims. Cylindrical core, cavernous, of the same kind of rock, and with the same organisms as the preceding. *Spirorbis*, *Serpula*.

(D. 60). Length 40 millims., width 50 millims. An irregular, cavernous piece of whitish-grey limestone, with *Pocillopora* and *Orbicella* (?). Echinid spines, *Spirorbis*.

(D. 61) [427]. Length 52 millims., width 75 millims. A conical piece of the same limestone as

preceding, partly compact, partly porous; it consists of *Madrepora contecta*, with the cœnenchymal platforms distinctly shown, and the interspaces vacant. *Amphistegina*, *Leptoclinum* stellates.

(D. 62–D. 64) [411]. Nodules and cylindrical core of cream-coloured limestone, with a total length of 132 millims. Cores of cream-coloured limestone, consisting of *Madrepora contecta*, encrusted by *Lithothamnion*. *Polytrema planum*.

(D. 65) [428]. Length 53 millims., width 76 millims. Cylindrical core, partially worn by the drill. Core principally of *Montipora*, the structure fairly well shown. The coral encrusted by *Lithothamnion*. *Orbitolites*, *Polytrema miniaceum*. Echinid spines. *Leptoclinum* stellates. *Cliona* borings.

(D. 66) [412]. Length 54 millims., width 78 millims. Cylindrical core of greyish-white, hard limestone, partly compact, partly porous, consisting of *Madrepora contecta*. *Polytrema miniaceum*, *Amphistegina Lessonii*, *Spirorbis*, *Cliona* borings. Encrusting *Lithothamnion*.

(D. 67) [413]. Length 30 millims., width 80 millims. Cylindrical core of greyish-white, compact, hard limestone, upper surface pitted, and with *Spirorbis* attached. Nearly altogether of *Madrepora contecta*, encrusted with *Polytrema planum* and *Lithothamnion*, and perforated by *Cliona* and other organisms. The coral is filled up solid with sclerenchyma, the borings are either vacant or infilled with crystalline material and sediment. *Polytrema miniaceum*. Echinid spines. *Leptoclinum* stellates.

(D. 68). Length 58 millims., width 75 millims. Limestone, similar to preceding. One moiety of the core of *Pocillopora*, in good preservation, the other of *Madrepora contecta*. *Spirorbis*.

(D. 69). Length 40 millims., width 67 millims. An irregular nodule, worn by the drill, of limestone, like the preceding, consisting of *Madrepora contecta*, encrusted partly by *Lithothamnion*.

(D. 70). Length 38 millims., width 70 millims. A nodule consisting of *Madrepora*, to which a piece of *Montipora* is attached. *Spirorbis*, *Serpula*-tubes. Encrusting *Lithothamnion*.

(D. 71). Length 23 millims., width 52 millims. A fragment of the usual greyish-white limestone, worn by the drill. It consists of *Madrepora contecta*, bored by *Cliona*.

(D. 72) [418]. Length 24 millims., width 48 millims. A flattened nodule of the usual hard limestone, the surface pitted, and with *Spirorbis* growing on it. *Madrepora contecta*, perforated by *Cliona*, &c., the excavations now infilled with fine consolidated sediment containing numerous detached stellate spicules of *Leptoclinum*. *Orbitolites* rare, *Polytrema miniaceum*, *P. planum*. Small gastropods. *Lithothamnion*. The minute structure of the coral is shown in the microscopic section.

(D. 73). Length 33 millims., width 52 millims. A nodular fragment of *Madrepora contecta*.

(D. 74) [414]. Length 37 millims., width 52 millims. An irregular nodule of greyish-white, compact limestone, mainly of *Madrepora contecta*, with an Astræan coral, *Orbicella* (?), attached. *Orbitolites*, *Carpenteria*, *Polytrema miniaceum*, and *P. planum*. *Spirorbis*. *Lithothamnion*.

Unconsolidated fine material, fine, light, greyish in tint, largely of fragmentary foraminifera, alcyonarian spicules, and polyzoa. The foraminifera belong principally to *Orbitolites*, *Planorbulina*, *Tinoporus*, and *Amphistegina*, with other genera enumerated above, many of which are only represented by single specimens. Also calcisponge spicules, echinid spines, ostracoda, and lamellibranchs.

(6) Notes on the Materials from the Lagoon Boring, "L."

The borings carried out by Mr. G. H. Halligan beneath the floor of the lagoon at Funafuti were situated about $1\frac{1}{2}$ miles west of the Mission House, where the depth of water was 101 feet at low-water spring tides. Two borings were made; the first reached a depth of 144 feet below the floor of the lagoon, and the second 113 feet. In both cases the attempts to penetrate deeper were baffled by meeting with solid limestone, too hard for the boring apparatus to pass through.

Samples of the rock materials, taken at various depths in the borings, as well as some from the floor of the lagoon, were forwarded to London. The rock from the borings appears to be entirely of carbonate of lime, without any admixture of dolomite. From the surface, to a depth of about 70 feet, the materials consist of calcareous organisms, entire and fragmentary—principally calcareous algæ—quite loose and apparently not cemented in any way. Below 70 feet the rock is a white, porous, rubbly limestone, partially consolidated by calcite, which, in the process of boring, has been broken up, so that the samples now consist of small angular fragments and much fine, powdery material. In the lower part of the boring the rock seems to have been more compact, and the fragments in the samples coarser, and there are in it many pieces of corals, which seem to have been broken off from colonies in position.

Depth from Floor of Lagoon, 0–62 *feet; Distance Bored*, 62 *feet; Numbers of Samples*, *L.* 2–*L.* 5.

The materials from the first part of the boring, to the depth of 62 feet, consist, to a very large extent, estimated between 80 and 95 per cent., of the detached fan-like joints or segments of the calcareous alga, *Halimeda*. According to Miss E. S. BARTON (Mrs. GEPP),* they all belong to *Halimeda opuntia*, LAMOUROUX, var. *macropus*, ASKENASY.

The individual joints are about 10 millims. in length, 13 millims. wide, and 1 millim. in thickness; some are entire, but a large number are now broken up into fragments, probably in the boring operations. They retain their minute structures perfectly, and Miss BARTON states that the specimens, from the depth of 35½ feet below the lagoon floor, were still sufficiently preserved to show the peripheral cells on decalcification, and at 50 feet the large central tubes were still to be recognised, but below that depth, though the form of the joint was retained, and the cells and tubes were distinctly shown, there was no cell-substance after treatment. The *Halimeda* remains from the borings are distinguished from those dredged up from the floor of the lagoon by their bleached appearance, and those from the depth of 22½ feet, when dry, are, if anything, lighter and more fragile than the recent surface specimens, but lower down in the boring, the cells and tubes of the joints become infiltrated to a varying extent with crystalline calcite, and are thus rendered heavier, more stony and resistant, so that they do not break readily between the fingers.

The segments are now quite free; not infrequently foraminifera, *Spirorbis*, &c., are attached to their smooth surfaces, and separate joints are sometimes completely encased by concentric layers of the encrusting foraminifer, *Polytrema planum*.

The foraminifera, from this part of the boring, are represented by a number of species and varieties, but they do not contribute to any extent to the mass of

* 'Linnean Soc. Journ.,' Botany, vol. 34, 1900, p. 481.

the materials. They have been carefully examined by Mr. F. CHAPMAN,* in connection with the recent forms distributed over the surface of the lagoon floor, which he has already described. The commoner forms belong to *Orbitolites*, *Sagenina*, *Textularia*, *Planorbulina*, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*, whilst those of sparse occurrence comprise *Spiroloculina*, *Miliolina*, *Placopsilina*, *Bdelloidina*, *Haddonia*, *Sagrina*, *Globigerina*, *Spirillina*, *Discorbina*, *Truncatulina*, *Anomalina*, *Carpenteria*, *Pulvinulina*, and *Polystomella*. The genera, and with a few doubtful exceptions, the species as well, have been recognised by Mr. CHAPMAN in the dredgings from the floor of the lagoon. With the exception of the naturally attached forms, the foraminifera, like the *Halimeda*-joints, are quite free, and their condition of preservation is practically the same as that of recent specimens.

Corals are not common in the materials from the upper part of the boring, the only forms met with are small broken fragments of *Seriatopora*, *Madrepora*, and *Porites*, a small specimen of *Heliopora cærulea*, and some detached alcyonarian spicules.

Other organisms found in this part of the boring include spicules of calcisponges, echinid spines, and plates, *Spirorbis*, *Serpula*-tubes, claws of small crustacea, *Leptoclinum* stellate spicules, polyzoa, *Thecidea maxilla*, small lamellibranchs and gastropods, and coprolitic pellets.

DETAILS.

(L. 2). 21½ feet. The sample is nearly entirely of the bleached *Halimeda*-joints, with foraminifera in the finer calcareous materials, principally belonging to *Sagenina frondescens*, *Gypsina globulus*, *G. vesicularis*, *Calcarina hispida*, *Amphistegina Lessonii*, and *Heterostegina depressa*. Altogether, Mr. CHAPMAN has determined twenty-four species and varieties; the greater number are rare. Echinid spines, *Serpula Bairdia*, polyzoa, small gastropods, and lamellibranchs. No coral fragments observed.

(L. 3) [451, 452]. 35½ feet. Very like the preceding in the great proportion of *Halimeda*-joints. These are now, to a certain extent, infilled with secondary carbonate of lime, and more rigid and stony than those found nearer the surface. Small fragments of rubbly and powdery limestone, in which *Seriatopora*, *Madrepora*, and *Porites* can be recognised, occur. Foraminifera are less numerous than in the preceding sample; the commoner forms belong to *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Microscopic sections of nodular fragments of the rock show consolidated calcareous sediment, with foraminifera, echinid spines, spicules of *Leptoclinum*, and small gastropods.

(L. 4). 50 feet. The sample from this depth contains the same large amount of *Halimeda*-joints as the samples above. The tubes and cells of the *Halimeda* are more generally infilled with the secondary carbonate of lime, but their minute structure is still well preserved. The only corals recognised are broken fragments of *Seriatopora*. All the genera of foraminifera present in the upper part of the boring occur in this sample, with the exception of *Globigerina*. Mr. CHAPMAN has determined thirty-nine species and varieties. Other organic constituents comprise spicules of calcisponges, echinid spines, *Serpula*, *Bairdia*, polyzoa, *Thecidea*, small lamellibranchs and gastropods, and coprolitic pellets.

(L. 5). 62 feet. The Halimeda-joints are as numerous and in the same condition of preservation as in the preceding samples. They are often encrusted by *Polytrema planum* and overgrown by a network of fine calcareous threads, possibly some other form of calcareous alga. Polyzoa and other organisms are also

* 'Linnean Soc. Journ.,' Zoology, vol. 28, pp. 161–210.

Truncatulina, *Calcarina*, *Gypsina*, *Polytrema*, *Amphistegina*, and *Heterostegina*. Mr. CHAPMAN has determined eleven species. No remains of corals were noticed in this sample.

(L. 7) [455]. 81½ feet. The white, porous, rubbly fragments of limestone consist of *Halimeda*-joints, foraminifera, and a few corals. *Halimeda* is more abundant, probably it forms half the rock. It is here hard and stony, and some of the joints are free The only corals noticed are fragments of *Seriatopora*, *Pocillopora*, and *Fungia*. The foraminifera belong to *Orbitolites*, *Sagenina*, *Haddonia*, *Textularia*, *Calcarina*, *Nonionina*, *Amphistegina* and *Heterostegina*; only the last two are common. Echinid plates and spines, *Serpula*, *Thecidea*, lamellibranchs and gastropods.

(L. 16). 82 feet. Six small irregular lumps of grey and greenish hard limestone from No. 2 bore-hole. They have been examined by Mr. H. M. BERNARD, who reports that four consist of *Heliopora cærulea*. The coral is extensively bored by *Cliona*, the surface is pitted, and *Spirorbis* is attached to it. Another piece is a fragment of *Cyphastræa*, and the remaining lump is mainly made up of alcyonarian spicules.

(L. 8) [456]. 94¼ feet. Irregular fragments of hard, whitish, rubbly limestone, consisting largely of corals, with a few foraminifera and a small amount of *Halimeda*. The corals belong to *Heliopora*, *Seriatopora*, plentiful, *Pocillopora*, common, *Madrepora* and *Porites*. The delicate branches of *Seriatopora* and *Madrepora* are, in some instances, partially decomposed, and will break up in the fingers, in some of the other corals the minute structure is retained. The more abundant foraminifera are: *Polytrema planum*, *Amphistegina Lessonii*, and *Heterostegina depressa*; the rarer forms are: *Textularia rugosa* and *Carpenteria utricularis*.

(L. 9) [457]. 103½ feet. Fragments and powder of whitish, porous, lightly cemented limestone with small cavities occupied by crystals of calcite. The rock is composed chiefly of corals and foraminifera. The corals belong to *Cœloria*, another Astræan genus, *Madrepora contecta*, and *Astræopora*. Their walls are generally preserved, but in some cases they have been dissolved and only the casts in consolidated sediment remain. Alcyonarian spicules. Foraminifera numerous, they apparently belong only to *Amphistegina* and *Heterostegina*. Only traces of *Halimeda*.

(L. 15). 105 feet. Fragments of whitish, hard, porous limestone, which Mr. H. M. BERNARD has examined. He recognises specimens of *Seriatopora*, referred provisionally to *S. pacifica*, BRUGGEMAN, which now lives on the reef. The rock contains also *Polytrema planum*, *Amphistegina* and *Halimeda*-joints in good preservation.

(L. 11, L. 12) [459, 460]. 106¾ feet. Fragments of limestone similar to the preceding, but very lightly cemented, so that the rock readily breaks up. The rock consists chiefly of corals and foraminifera. The former include *Lobophytum*, *Seriatopora*, undetermined Astræan, *Madrepora* and *Montipora*, encrusted by *Polytrema planum*. Foraminifera numerous, chiefly *Amphistegina* and *Heterostegina*. Echinid spines, lamellibranchs and gastropods. *Halimeda*, not uncommon and in fair preservation, it is consolidated with the other organisms.

(L. 10) [458]. 112½ feet. Whitish-grey rubbly limestone, composed mainly of corals and foraminifera. The coral fragments belong to *Seriatopora* (rare), *Madrepora*, *Goniopora* and *Montipora*, their structure is usually preserved, and the interstices are either empty or infilled with crystalline material or consolidated sediment. Foraminifera numerous, the same forms as in the sample above. *Halimeda* not uncommon.

(L. 13) [461, 462]. 116-144 feet. Sample of fragments of limestone, composed chiefly of corals and foraminifera, like the preceding. The sample has been submitted to Mr. BERNARD, who reports that it contains "fragments of *Madrepora* and a single fragment which may be either *Madrepora* or *Montipora*. The greater number of fragments are not coral or only coral *débris* mixed with other organisms."

A microscopic section of some of the rock fragments shows that the minute structure of the corals is preserved and their interstices are either empty or infilled with fine consolidated sediment containing numerous stellate spicules of *Leptoclinum*. The principal foraminifera are *Polytrema*, *Amphistegina* and *Heterostegina*. In a microscopic section the following additional genera were determined by Mr. CHAPMAN:—*Miliolina*, *Globigerina*, *Discorbina*, *Planorbulina*, *Calcarina* and *Gypsina inhærens*. Echinid spines, *Serpula*, *Spirorbis* and lamellibranchs. *Halimeda*-joints, branching and encrusting *Lithothamnion*, with the structure well preserved.

(L. 14–L. 14A) [463]. 116–144 feet. Fragments of the same whitish, hard, rubbly limestone as in the beds immediately above. Some of the fragments are pieces of corals, in others no structure can be seen with a lens. The corals are usually well-preserved, but in some instances they are decomposed and crumble between the fingers. Mr. BERNARD has determined an Astræan, genus uncertain, a single fungid, two species of *Madrepora*, one common, with the branches in fair preservation, showing axial and radial corallites, with cœnenchyma and sometimes surface striation, *Montipora*, *Goniopora* and *Astræopora*, of which there are many fragments.

In the same sample there were also many broken pieces of *Heliopora cœrulea*, in a bleached condition and greatly perforated by *Cliona*. The foraminifera include *Planorbulina*, *Globigerina*, *Calcarina*, *Gypsina*, *Polytrema planum*, *Amphistegina* and *Heterostegina*. A microscopic section of a piece of the rock shows that the structure of the foraminifera is well preserved, they are embedded in very fine consolidated sedimentary material, which apparently consists of the *débris* of these organisms and spicules of *Leptoclinum*. Echinid spines, polyzoa, *Thecidea*, lamellibranchs (including *Lithodomus*) and gastropods. *Halimeda*-joints, retaining their minute structure, and *Lithothamnion*.

(L. 14E) [464–465]. 116–144 feet. The rock fragments are generally very similar to the preceding (L. 14), but the rock is of a harder character; it consists chiefly of corals, foraminifera and *Lithothamnion*, &c. At a rough estimate about half the rock, as shown in the sample, consists of corals. They belong to *Seriatopora*, *Pocillopora*, *Fungia*, *Madrepora* (chiefly fragments of sub-cylindrical branches, 10–20 millims. in length by 6–8 millims. in thickness), *Montipora* and *Astræopora*. A portion of a stem of *Lobophytum*, measuring 27 by 32 by 7 millims., is shown with the spicules standing out on the surface. Foraminifera are fairly numerous; those recognisable with a lens belong to *Amphistegina* and *Heterostegina*. *Halimeda*, common, and *Lithothamnion*, showing in microscopic sections the structure very distinctly.

A striking feature of the boring beneath the floor of the lagoon is the large amount of the calcareous alga, *Halimeda opuntia*, var. *macropus*, in the upper half of the boring. To a depth of over 60 feet the beds are principally composed of the detached joints of this alga, which are, judging from the samples, quite free, and not cemented together in any way. With the *Halimeda* there is a small proportion of foraminifera, corals and fragments of other organisms. Between 62 and 80 feet the amount of *Halimeda* diminishes to about one-half, and the joints in this portion are no longer free, but cemented by calcite, together with foraminifera, into rubbly rock. At the level of 94 feet and to the bottom of the boring the *Halimeda* forms only a slight percentage of the rock; at the lower levels the minute structure is retained as a rule almost unchanged. There is no close parallel in the other borings at Funafuti to these *Halimeda* deposits beneath the lagoon; although some parts of the Main Boring, between 637 and 748 feet from the surface, chiefly consist of *Halimeda* and foraminifera, the relative amount of the former is much less than in the Lagoon Boring.

The character of the rock in the lower 50 feet of the Lagoon Boring does not differ much from that in the higher part of the Main Boring. The same organisms are present in both, and the corals and foraminifera in the Lagoon Boring are better preserved and less altered than those at corresponding depths in the Main Boring.

(7) NOTES ON THE ORGANISMS FROM THE FUNAFUTI BORINGS.

The organisms which form by far the larger mass of the core materials from the different borings at Funafuti belong to foraminifera, corals, and calcareous algæ, while

another group, subordinate as regards the amount of material contributed by it collectively to the rock from the borings, comprises the remains, mostly fragmentary, of sponges, echinids, annelids, crustacea, polyzoa, ascidians, lamellibranchs, and gastropods.

These organisms are usually commingled together in the cores in various proportions; very frequently we find, however, a preponderance of one or other of the principal groups, such as foraminifera or corals, and occasionally of the calcareous algæ, through a variable thickness of the rock, one form continuing for a period and then gradually giving way to the predominance or perhaps the exclusive occurrence of another. This alternation is more noticeable in regard to the corals and foraminifera in the lower part of the Main Boring, where the solid cores, for a thickness of several inches or even of some feet, are largely composed of foraminifera, with here and there a small coral, some calcareous algæ, and an admixture of the *débris* of other organisms and fine sediment, and then are succeeded by cores which consist mainly of corals with a scanty number of foraminifera filling in the interspaces, and often a considerable amount of *Lithothamnion* and the *débris* of the smaller organisms. There is no regularity in the period of the dominance either of corals or foraminifera, but on the whole the foraminifera appear to contribute a notably larger amount of the rock than the corals. Although the calcareous algæ form an important part of the rock in various parts of the boring, they do not, as a rule, so largely predominate in particular portions as in the case of the groups just referred to, but they are more generally associated with corals. There are, however, some exceptions, for some of the rock cores in the upper part of the Main Boring are largely composed of branching *Lithothamnion*, and the beds beneath the lagoon floor mainly consist of *Halimeda*.

The various organisms from the borings all belong to existing genera, and with some exceptions the species, as far as they can be determined, are also still living. The greater number have been recognised in the dredgings from the outer slopes of the reef and from the lagoon, and in the collections made on the reef at Funafuti; some, however, have not yet been met with in the recent fauna of the locality.

In the following tables, lists of the genera of the various organisms present in the borings are given, showing in one case their range of occurrence, and in another their distribution in the various cores.

(7A) Notes on the Foraminifera from the Funafuti Borings.

The abundance of the foraminifera, both in the solid rock-cores and in the loose materials from the borings, indicates that they have taken quite as important a share in forming the earlier stages of the reef as of those now in progress. In some parts of the Main Boring, where the rock has been largely altered by dolomitisation, their walls have been broken down and partially obliterated, though not to the extent to prevent recognition, but on the whole their structures have been well preserved. The

LIST of Genera of Foraminifera, showing their Range of Occurrence in the different Borings.

Families.	Genera.	Range in feet from surface.			Range in feet from lagoon floor.
		Main Boring.	First Boring, C.	Second Boring, D.	Lagoon Boring L.
Miliolidæ . .	*Nubecularia*, DEFR.	1–350	1–50		
,, . .	*Spiroloculina*, D'ORBIGNY	120–844	..	40	21–62
,, . .	*Miliolina*, WILLIAMSON	65–1113	1–90	40	50–144
,, . .	*Ophthalmidium*, KÜBLER	812			
,, . .	*Cornuspira*, SCHULTZE	...	...	40–70	
,, . .	*Peneroplis*, MONTFORT	854			
,, . .	*Orbitolites*, LAM.	1–1114	1–105	50–72	50–82
,, . .	*Alveolina*, D'ORB.	660?–740			
Astrorhizidæ .	*Sagenina*, CHAPMAN	...	...	...	21–82
Lituolidæ . .	*Placopsilina*, D'ORB	25–973	1–30	...	21–62
,, . .	*Bdelloidina*, CARTER	742	...	...	50
,, . .	*Haddonia*, CHAPMAN	3–980	1–30	...	35–82
Textularidæ .	*Textularia*, DEFR.	65–1114	90	...	21–144
,, .	*Verneuilina*, D'ORB.	...	90		
,, .	*Gaudryina*, D'ORB.	1013			
,, .	*Valvulina*, D'ORB.	1009	30–50	...	21
,, .	*Bolivina*, D'ORB.	330–863	...	40	
,, .	*Marginulina*, D'ORB.	255			
Lagenidæ . .	*Cristellaria*, LAM.	65–160	...	40	
,, . .	*Sagrina*, PARKER and JONES	65	...	40–70	21
Globigerinidæ .	*Globigerina*, D'ORB.	25–1109	...	...	21
,, .	*Pullenia*, PARKER and JONES	...	...	70	
Rotalidæ . . .	*Spirillina*, EHR.	65	...	30–70	50–62
,, . . .	*Patellina*, WILL.	...	...	40	
,, . . .	*Cymbalopora*, HAG.	220–643	...	40	
,, . . .	*Discorbina*, PARKER and JONES	65–747	50–80	70	35–144
,, . . .	*Planorbulina*, D'ORB.	37–1109	30–80	70	21–144
,, . . .	*Truncatulina*, D'ORB.	65–680	90	...	21–75
,, . . .	*Anomalina*, PARKER and JONES	170–370	...	...	50
,, . . .	*Carpenteria*, GRAY	18–1114	30–90	12–74	50–94
,, . . .	*Pulvinulina*, PARKER and JONES	70–1077	90	40–70	21–62
,, . . .	*Rotalia*, LAM.	90?			
,, . . .	*Calcarina*, D'ORB.	240–1113	90	12–70	35–144
,, . . .	*Tinoporus*, CARP.	1–373	...	40–70	
,, . . .	*Gypsina*, CARTER	5–1114	1–90	50–60	21–144
,, . . .	*Polytrema*, RISSO	1–1114	1–85	12–72	21–144
Nummulinidæ .	*Nonionina*, D'ORB.	140–888	80–85	...	21–82
,, .	*Polystomella*, LAM.	...	...	...	50
,, .	*Amphistegina*, D'ORB.	1–1114	1–105	12–72	21–144
,, .	*Heterostegina*, D'ORB.	65–1114	90	70	21–144
,, .	*Cycloclypeus*, CARP.	567–1074			

when there is a break, and it reappears at the depth of 660 feet, and is present sometimes in great numbers in most of the solid cores down to 770 feet; below this level it only occurs sporadically at the depth of 1035, 1042 and 1074 feet. The cores in which this form is most abundant between 660 and 770 feet from the surface, are

very largely composed of foraminifera and *Halimeda*-joints, whilst corals are only sparsely present. *Cycloclypeus* has only been met with in the Main Boring. According to Mr. CHAPMAN* it has not been found in the lagoon dredgings; in those from the outer slopes of the reef it occurs from 30–200 fathoms.

(7B) NOTES ON THE CORALS FROM THE FUNAFUTI BORINGS.†

Reference has already been made to the important changes which the corals in the borings have undergone in the course of fossilisation, and to the difficulties arising therefrom in determining their original characters and affinities. Throughout the three shallower borings, and in the Main Boring to a depth of about 180 feet from the surface, the corals in the cores retain their walls and other structures, as a rule, in fair preservation, although many of their characters are much obscured by the way in which their interstices have been infilled with a secondary deposit of fibro-crystalline carbonate of lime, which often closely simulates the natural structures of the corals. At greater depths in the boring, the corals for the most part have been dissolved, leaving casts of fine calcareous sediment or of crystalline materials, which in some cases remain empty, whilst in others they are refilled with crystalline calcite or dolomite. Very frequently also the coral has been entirely dissolved away, leaving a cavity bounded by consolidated calcareous sediment, which bears the imprint of the exterior surface of the coral, and within the hollow there is an interlacing network of delicate fibrous threads and nodes, which are the tubes made by boring sponges and other organisms, now solidly infilled with sediment. The dissolution of the corals in the borings could obviously have taken place only after the consolidation of the calcareous mud which had covered them.

Owing to these unfavourable changes, the minute structural details, on which the specific characters of recent corals depend, are usually obliterated in these fossil forms, and even the characteristic generic features of some of the closely allied Astræan corals are no longer recognisable. The determination of the genera and species in well preserved recent corals is often very difficult, owing to their wide range of variability, but in the case of most of the fossil Funafuti specimens complete identification is well nigh hopeless. It seems highly probable, however, that they all belong to known genera of reef-building corals, and most of the species appear to be closely allied to, if not the same as, those already described. In only a single instance has there been sufficient ground for regarding a form as a new species.

As shown in the accompanying list, the corals from the borings comprise 2 genera of Hydrocorallinæ, 2 of Alcyonaria, 13 of Madreporaria Aporosa, 10 of which belong to the Astræidæ family, 5 of Madreporaria Fungida, and 6 of M. perforata. With the single exception of *Goniopora*, these genera are all present in the Main Boring,

* 'Linnean Soc. Journ.,' Zoology, vol. 28 (1900), pp. 21–26.

† As previously mentioned, for the sake of convenience, Alcyonaria and Hydrocorallinæ are included with the Madreporaria under the general term "Corals" in this report.

LIST of Genera of Foraminifera, showing their Range of Occurrence in the different Borings.

Families.	Genera.	Range in feet from surface. Main Boring.	First Boring, C.	Second Boring, D.	Range in feet from lagoon floor. Lagoon Boring L.
Miliolidæ	*Nubecularia*, DEFR.	1–350	1–50		
"	*Spiroloculina*, D'ORBIGNY	120–844	...	40	21–62
"	*Miliolina*, WILLIAMSON	65–1113	1–90	40	50–144
"	*Ophthalmidium*, KÜBLER	812			
"	*Cornuspira*, SCHULTZE	...	...	40–70	
"	*Peneroplis*, MONTFORT	854			
"	*Orbitolites*, LAM.	1–1114	1–105	50–72	50–82
"	*Alveolina*, D'ORB.	660?–740			
Astrorhizidæ	*Sagenina*, CHAPMAN	...	...	...	21–82
Lituolidæ	*Placopsilina*, D'ORB.	25–973	1–30	...	21–62
"	*Bdelloidina*, CARTER	742	...	...	50
"	*Haddonia*, CHAPMAN	3–980	1–30	...	35–82
Textularidæ	*Textularia*, DEFR.	65–1114	90	...	21–144
"	*Verneuilina*, D'ORB.	...	90		
"	*Gaudryina*, D'ORB.	1013			
"	*Valvulina*, D'ORB.	1009	30–50	...	21
"	*Bolivina*, D'ORB.	330–863	...	40	
"	*Marginulina*, D'ORB.	255			
Lagenidæ	*Cristellaria*, LAM.	65–160	...	40	
"	*Sagrina*, PARKER and JONES	65	...	40–70	21
Globigerinidæ	*Globigerina*, D'ORB.	25–1109	...	...	21
"	*Pullenia*, PARKER and JONES	...	...	70	
Rotalidæ	*Spirillina*, EHR.	65	...	30–70	50–62
"	*Patellina*, WILL.	...	...	40	
"	*Cymbalopora*, HAG.	220–643	...	40	
"	*Discorbina*, PARKER and JONES	65–747	50–80	70	35–144
"	*Planorbulina*, D'ORB.	37–1109	30–80	70	21–144
"	*Truncatulina*, D'ORB.	65–680	90	...	21–75
"	*Anomalina*, PARKER and JONES	170–370	...	...	50
"	*Carpenteria*, GRAY	18–1114	30–90	12–74	50–94
"	*Pulvinulina*, PARKER and JONES	70–1077	90	40–70	21–62
"	*Rotalia*, LAM.	90?			
"	*Calcarina*, D'ORB.	240–1113	90	12–70	35–144
"	*Tinoporus*, CARP.	1–373	...	40–70	
"	*Gypsina*, CARTER	5–1114	1–90	50–60	21–144
"	*Polytrema*, RISSO	1–1114	1–85	12–72	21–144
Nummulinidæ	*Nonionina*, D'ORB.	140–888	80–85	...	21–82
"	*Polystomella*, LAM.	...	...	...	50
"	*Amphistegina*, D'ORB.	1–1114	1–105	12–72	21–144
"	*Heterostegina*, D'ORB.	65–1114	90	70	21–144
"	*Cycloclypeus*, CARP.	567–1074			

when there is a break, and it reappears at the depth of 660 feet, and is present sometimes in great numbers in most of the solid cores down to 770 feet; below this level it only occurs sporadically at the depth of 1035, 1042 and 1074 feet. The cores in which this form is most abundant between 660 and 770 feet from the surface, are

LIST of Genera and Species of Corals, showing their Range of Occurrence in the different Borings.

Families.	Genera and species.	Range in feet from surface. Main Boring.	First Boring, C.	Second Boring, D.	Range in feet from lagoon floor. Lagoon Boring, L.
	HYDROZOA.				
	HYDROCORALLINÆ.				
Milleporidæ	*Millepora*, LINN.	1-1112	80	30-60	
„	„ *nodosa*, ESPER.	1-120			
Stylasteridæ	*Stylaster*, GRAY	75			
	ACTINOZOA.				
	ALCYONARIA.				
Alcyonidæ	*Lobophytum*, MARENZ.	1-1112	...	...	116-144
	Spicules detached	40-1113	90	40-70	62-82
Heliopoiidæ	*Heliopora cærulea*, PALLAS	1-210	1-105	40-50	62-144
	MADREPORARIA APOROSA.				
Oculinidæ	*Stylophora*, M.ED. and H.	32-1114	50-105		
Pocilloporidæ	*Seriatopora*, LAM.	430-1086	...	...	35-112
„	*Pocillopora*, LAM.	10-1114	80-85	60-72	81-144
„	„ *cf. glomerata*, GARD.	90			
Astræida	*Euphyllia*, DANA	1075			
„	*Cœloria*, M.-ED. and H.	340-1108	...	...	103
„	„ *cf. dædalea*, ELL. and SOL.	785			
„	*Astræa*, LAM.	6-1105	50-85		
„	„ *cf. denticulata*, ELL. and SOL.	790			
„	„ *lobata*, M.-E. and H.	600-977			
„	*Goniastræa*, M.-ED. and H.	210-1104			
„	„ *cf. eximia*, DANA	765			
„	„ *solida*, BLAINV.	957			
„	*Prionastræa*, M.-ED. and H.	531?-1025			
„	„ *cf. magnifica*, BLAINV.	944-1025			
„	*Orbicella*, DANA	82-1103	1-105	12-72	
„	„ *heliopora*, LAM.	95-753			
„	„ *cf. acropora*, LINN.	751-778			
„	„ *cf. orion*, DANA	803			
„	„ *cf. funafutensis*, GARD.	914			
„	„ *pleiades*, ELL. and SOL.	1011-1089			
„	*Hydnophora*, M.-ED. and H.	642?-921			
„	„ *microcona*, LAM.	749			
„	*Cyphastræa*, M.-ED. and H.	654-1108	...	...	82
„	„ *cf. Savignyi*, M.-E. and H.	654			
„	*Galaxea*, OKEN	765-950			
	„ *cf. Lamarcki*, M.-ED. and H.	904-910			
	„ *cf. Ellisi*, M.-ED. and H.	949-950			

List of Genera and Species of Corals—*continued.*

Families.	Genera and species.	Range in feet from surface. Main Boring.	First Boring, C.	Second Boring, D.	Range in feet from lagoon floor. Lagoon Boring, L.
	MADREPORARIA FUNGIDA.				
	Siderastræa, BLAINV.	1019?–1110			
Fungidæ	*Fungia*, DANA	100–1091	80– 85	...	82–144
„	*Halomitra*, DANA	530?			
Lophoseridæ	*Cycloseris*, M.-ED. and H.	716–1075?			
„	„ cf. *cyclolites*, LAM.	736			
„	*Psammocora*, DANA	973–1064	30 –50		
	MADREPORARIA PERFORATA.				
Madreporidæ	*Madrepora*, LINN.	1–1114	85	12–72	35–144
„	„ *contecta*, *sp. n.*	2– 972		12–72	103
„	*Turbinaria*, OKEN	652–1104			
„	*Astræopora*, BLAINV.	88–1030	...	...	103–144
	Montipora, QUOY and GAIMARD.	30–1063	30– 105	12–72	106–144
Poritidæ	*Porites*, LAM.	9–1113	...	40–60	35–94
„	„ *arenosa*, ESPER.	782–1043			
„	*Goniopora*, QUOY and GAIM.	...	...	...	112–144

and they are all well-known genera of reef-building corals. Of the 28 genera recorded from the borings, 22 are living at the present time on the reefs, or in the lagoon at Funafuti; the 6 genera not recognised as at present existing in the region are *Stylaster*, *Euphyllia*, *Galaxea*, *Siderastræa*, *Cycloseris*, and *Goniopora*. The range of depth in the borings of the different genera is very variable. The commoner forms, such as *Millepora*, *Lobophytum*, *Stylophora*, *Pocillopora*, *Astræa*, *Orbicella*, *Fungia*, *Madrepora*, *Astræopora*, *Montipora*, and *Porites*, range from the top to the bottom of the Main Boring, but not continuously, for a particular form which has flourished through a series of consecutive cores will often disappear altogether for a variable interval, and then comes in again. The genera of comparatively rare occurrence, such as *Hydnophora*, *Galaxea*, *Cycloseris*, and *Turbinia*, are apparently restricted to the lower third of the Main Boring.

HYDROCORALLINÆ.

GENUS MILLEPORA, LINN.

This genus is common in the Main Boring from the surface to the depth of 125 feet. Between this level and 930 feet it has only been met with sporadically at very wide intervals; from 930 feet to the bottom of the boring it is again frequent. It is rare

in the First and Second Borings. The only species recognised is *M. nodosa*, ESPER. This species, with three others of the genus, have been determined by WHITELEGGE,* at Funafuti.

GENUS STYLASTER, GREY.

Only a single small fragment was observed in unconsolidated material from the depth of 75 feet in the Main Boring. No recent example of the genus has been recorded at Funafuti.

ALCYONARIA.

GENUS LOBOPHYTUM, MARENZELLER.

Fragments of the cylindrical or compressed basal stem of forms of this genus, embedded in the solid cores, are present occasionally at various depths throughout the Main Boring, and also in the Lagoon Boring. They consist of a mass of fusiform tubercular spicules, reaching to 2 millims. in length by 0·5 millim. in thickness, which are nearly in contact, and without orientation. The minute spaces between the spicules are filled with the matrix of crystalline calcite, or dolomite, or occasionally with consolidated sediment. The stem fragments are now generally encrusted by layers of *Polytrema* and *Lithothamnion*, and to this envelopment their preservation as stems is partly due.

Detached spicules of the same form as those in the stems are present in great numbers, both in the solid cores, and in the unconsolidated materials, throughout all the borings, and they materially contribute to the mass of the rock. These spicules are more resistant to change than the skeletons of Madreporarian corals; they retain their fibro-crystalline characters when the structures of the corals associated with them in the same cores have been destroyed and obliterated. The genus *Lobophytum*, to which the stem-fragments and detached spicules are referred, is now represented by several species, which, according to WHITELEGGE,† flourish plentifully in the small reefs of the lagoon at Funafuti.

GENUS HELIOPORA, BLAINVILLE.

HELIOPORA CÆRULEA, PALLAS.

This form occurs frequently in the Main Boring, in a well-preserved condition, between 1–100 feet; it appears again in the form of decayed casts at 190–210 feet; below this level it has not been met with. It is also common in the First Boring, but rare in the Second; pieces of it are also present in the Lagoon Boring at 62–144 feet below the floor. Professor SOLLAS‡ calls attention to this species, which with *Porites* forms a dead coral-reef slightly above the sea-level at low water, in the Mangrove Swamp at Funafuti; Mr. STANLEY GARDINER§ dredged up a small living piece on the

* Mem. III., Austral Mus., Sydney, part 7, 1899, pp. 374–377.

† *Ibid.*, 1897, p. 214.

‡ 'Roy. Soc. Proc.,' vol. 60, 1897, p. 510.

§ 'Cambridge Phil. Soc. Proc.,' vol. 9, part viii, 1898, p. 436.

outer slopes of the reef at 35 fathoms, and Mr. HEDLEY* found it alive and flourishing at low-water mark at the boat entrance of Nukulailai, an atoll about 65 miles south of Funafuti.

MADREPORARIA APOROSA.

GENUS STYLOPHORA, MILNE-EDWARDS and HAIME.

Small colonies of this genus occasionally occur in the Main Boring at long intervals apart. At the depth of 990 feet and from this to the bottom of the boring, they are more numerous and are present in nearly all the cores. The genus is also represented in the First Boring. It has not been possible to distinguish the species. J. STANLEY GARDINER† has recognised seven species on the outer reef and in the lagoon at Funafuti, between 5—30 fathoms.

GENUS SERIATOPORA, LAM.

This genus has been met with in the Main Boring between 430—1086 feet. Except in the lower part of the boring, it is not common. It is also present in the Lagoon Boring. The corallum is usually dissolved away leaving a hollow mould with the imprints of the calices in hardened sediment. J. S. GARDINER‡ records two species living at Funafuti at the depth of 20 fathoms.

GENUS POCILLOPORA, LAM.

This genus is represented in all the borings, and is one of the commonest forms. In the Main Boring, from near the surface to 750 feet, it is sporadic in its occurrence; below this depth to the bottom of the boring it is very abundant. Segmental casts of the corallites are frequent in unconsolidated material; the surface characters are seldom shown. Only one species has been distinguished. From the outer reef at depths of 5—30 fathoms, and from the lagoon at Funafuti, Mr. J. S. GARDINER§ describes fourteen species and varieties, but these are so variable that he is "doubtful whether all these so-called species should not rather be described as varieties of one species, the characters of which would be the characters of the whole genus."

GENUS EUPHYLLIA, DANA.

Only the cast of an imperfect specimen was met with in the Main Boring at 1075 feet. This genus has not been noticed in the recent fauna of the atoll.

GENUS CŒLORIA, M.-ED. and H.

This genus was first observed in the Main Boring at 340 feet; below this it occurs rarely as casts, at long intervals apart, down to 875 feet; from this to the bottom of

* Mem. III., Austral. Mus., Sydney, p. 308.

† 'Zool. Soc. Proc.,' 1898, pp. 995-1000.

‡ *Ibid.*, 1897, pp. 952, 953.

§ *Ibid.*, pp. 942—952.

the boring it is fairly common and some specimens are in their position of growth. It is also present in the Lagoon Boring. Only one species, *C. dædalea*, ELL. and SOL., has been determined. According to J. S. GARDINER,* the genus is very abundant on the lagoon shoals and also at a depth of 7 fathoms on the outer reefs at Funafuti, and three species are recorded.

GENUS ASTRÆA, LAM.

This genus extends throughout the Main Boring, but it is of rare occurrence until reaching a depth of 845 feet; from this to the bottom of the boring it is common. Two species have been recognised, *A. denticulata*, ELL. and SOLL., and *A. lobata*, M.-ED. and H., both of which are now living in the lagoon and outer reefs of Funafuti.

GENUS GONIASTRÆA, M.-ED. and H.

A specimen of the genus occurs at the depth of 210 feet in the Main Boring, no other forms have been noticed till reaching 765 feet; from this to nearly the bottom of the boring it is present at intervals. Two species have been determined, one *G. solida*, BLAINV., the other is closely allied to *G. eximia*, DANA. No living forms have been recorded at Funafuti.

GENUS PRIONASTRÆA, M.-ED. and H.

A cast of a specimen referred with doubt to this genus has been met with in the Main Boring at 531 feet, below this the genus is represented sparsely at long intervals down to 1025 feet. Some forms approach closely to *P. magnifica*, BLAINV. J. S. GARDINER† has determined a living species at Funafuti.

GENUS ORBICELLA, DANA.

This genus is found rarely in the Main Boring between 82–914 feet; below this to the bottom of the boring it occurs frequently. It is also not uncommon in the First and Second Borings. *O. heliopora*, LAM. and *O. pleiades*, ELL. and SOL. have been determined; other forms are allied to *O. acropora*, LINN., *O. orion*, DANA, and *O. funafutensis*, GARD. J. S. GARDINER‡ has described seven species now living on the leeward reef and in the lagoon at Funafuti.

GENUS HYDNOPHORA, M.-ED. and H.

Casts of three examples of the genus have been met with in the Main Boring between 642 and 921 feet. One belongs to *H. microcona*, LAM., which has also been recognised by J. S. GARDINER§ in the lagoon shoals at Funafuti.

* 'Zool. Soc. Proc.,' 1899, pp. 740–744.
† *Ibid.*, p. 760.
‡ *Ibid.*, pp. 752–757.
§ *Ibid.*, p. 744.

GENUS CYPHASTRÆA, M.-ED. and H.

This genus occurs very sparingly in the Main Boring between 654 and 1108 feet, one of the casts resembles *C. Savignyi*, M.-ED. and H. At the depth of 82 feet in the Lagoon Boring a fragment has likewise been found. A recent species is recorded by WHITELEGGE* from the passage between the islets of the reef at Funafuti.

GENUS GALAXEA, OKEN.

The genus is sparsely represented in the Main Boring between 765 and 950 feet. The casts indicate two species, one allied to *G. Lamarcki*, M.-EDW. and H., the other to *G. Ellisi*, M.-EDW. and H. According to HEDLEY† this genus has not been met with as recent at Funafuti.

In addition to the above, the cores of the lower part of the Main Boring contain numerous casts of Astræan corals not sufficiently preserved for their generic characters to be distinguished.

MADREPORARIA FUNGIDA.

GENUS SIDERASTRÆA, BLAINVILLE.

This genus has only been met with in the lower part of the Main Boring, between 1019 and 1110 feet. No recent form has been observed at Funafuti.

GENUS FUNGIA, DANA.

This genus is represented by casts and fragments in the Main, First, and Lagoon Borings. It appears in the Main Boring at the depth of 100 feet, and again at 578 feet; below this depth to near the base of the core it is not infrequent, but the specimens are all too imperfect for specific determination. According to J. S. GARDINER‡ dead specimens of the genus are not uncommon on the beaches of the outer islands at Funafuti, indicating that it must flourish close outside the reef.

GENUS HALOMITRA, DANA.

An imperfect cast from a depth of 530 feet in the Main Boring probably belongs to this genus. J. S. GARDINER§ describes a new species of the genus from the lagoon shoals at Funafuti.

GENUS CYCLOSERIS, M.-ED. and H.

Casts of this genus are not infrequent between 716–766 feet in the Main Boring, below this level they occur at long intervals to nearly the bottom of the boring. The forms are closely allied to *C. cyclolites*, LAM. The genus has not been noticed in the recent forms of Funafuti.

GENUS PSAMMOCORA, DANA.

This genus has been found in the First Boring and nearly at the base of the Main Boring. J. S. GARDINER|| describes several recent species from the lagoon shoals and the outer reef at Funafuti.

* Mem. III., Austral. Mus., Sydney, 1898, p. 354.

† *Ibid.*, p. 350.

‡ 'Zool. Soc. Proc.,' 1898, p. 526.

§ *Ibid.*, p. 528.

|| *Ibid.*, pp. 536–539.

Madreporaria Perforata.

Genus Madrepora, Linn.

This genus is the most common and widely distributed of all the corals in the borings at Funafuti. In the Main Boring it is present very generally from the surface down to 150 feet, and many of the solid cylindrical cores are nearly entirely composed of masses of it in position of growth. Then there is an interval of over 200 feet, in which it has not been noticed; it reappears at the depth of 375 feet, and extends, with occasional breaks, to the bottom of the boring. In the Second Boring (D) it is equally as prominent as in the upper part of the Main Boring. It is probable that several species are represented in the cores, but, with one exception, they are not sufficiently preserved to allow of satisfactory diagnosis and comparison with recent forms of the genus. The exceptional species is very abundant, and the examples of it from the cores near the surface are in good condition; it possesses certain features, more particularly an unusual development of the cœnenchyma, which distinguish it from any recent form with which I have been able to compare it. I have, therefore, been constrained to regard it provisionally as a new species, and have referred to it in this report under the name of *Madrepora contecta.* Its characters are given below.

Madrepora contecta, sp. n. Corallum consisting of a massive base, from which robust, dichotomous branches are given off. The branches are 8–22 millims. in diameter, they have a generally upright direction, and they diverge at acute angles. The outer surface of the branches is longitudinally or obliquely striate. The interspaces between the branches are occupied by a growth of laminate cœnenchyma, which completely envelopes the branches and binds their lower portions into a continuous mass.

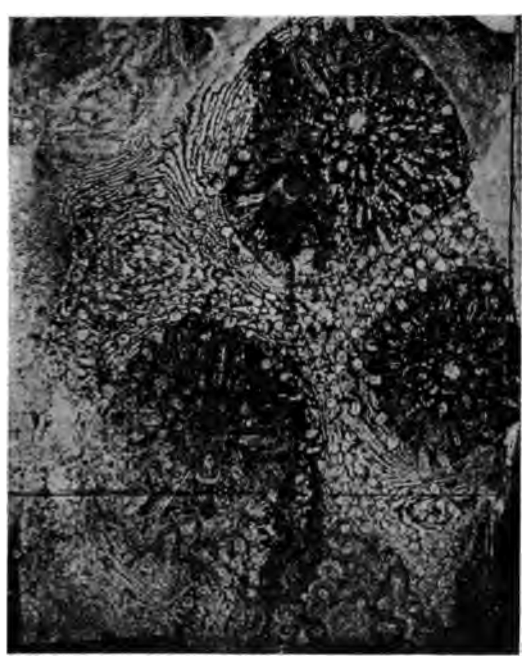


Fig. 21.—Part of a transverse section of a mass of *Madrepora contecta*, showing the branches of the coral completely surrounded by the laminate cœnenchyma. Enlarged 1½ diameters, nearly.

From the Main Boring, core 52, depth 40–50 feet, slide 619.

The axial corallites are sub-circular, 4–4·5 millims. across, the walls are thick, the calicinal aperture is about 1·3 millim. wide, and there are twelve septa. The radial corallites are thickly grouped round the axial, they are 2–2·5 millims. in thickness, the calices are about 1 millim. in width, with six to ten septa; their free distal ends are not shown in the specimens from the cores. In the cœnenchyma there are numerous fully immersed corallites, at varying distances apart, sometimes separated by less than their own diameters, at others very sparsely scattered; they are elongate, cylindrical, the walls are simple, the calices 0·75–1 millim. in width, with weak curved septa, and at intervals they are traversed obliquely by dissepiments or tabulæ.

The cœnenchyma consists of a series of thin, horizontal, or slightly arched platforms or layers, supported by numerous vertical spines or pillars; the layers are about 0·26 millim. apart, and in places imperforate,

in places with minute pores. The immersed corallites and the layers of the cœnenchyma contrast greatly with the short radial corallites of the branches, and more particularly as the latter are now thickened or solidly infilled with sclerenchyma, whilst the cœnenchyma with its corallites usually remain thin.

Fig. 22.—Part of a vertical section of the same coral, showing in the centre a small upright branch, and on the left of the figure part of another branch; the intermediate areas are occupied by the laminate cœnenchyma. Enlarged $1\frac{1}{2}$ diameters, slide 619A.

Perfect specimens of this form have not been obtained, but judging from some of the cores of it, which are 158 millims. in length by 103 millims. in width, it appears to have grown in large masses. It is very common in the Main Boring to a depth of 110 feet, and it also occurs in the condition of casts at intervals to the depth of 972 feet. It is likewise present throughout the Second Boring (D) and in the Lagoon Boring. Specimens have been submitted to Mr. J. STANLEY GARDINER, who states that they differ from any of the recent species collected by him at Funafuti, and they appear to be closely allied to *M. pacifica*, BROOK. Mr. GARDINER considers that *M. contecta* cannot have grown at a depth of more than about 20 fathoms below the surface, and probably it lived at less than half this depth.

The genus *Madrepora* appears also to have been the best represented of the recent corals at Funafuti. Mr. J. S. GARDINER* has determined thirteen species (including one new) from the lagoon shoals and outer reef, and Mr. WHITELEGGE† eight species and one variety (two of which and the variety are new). With one exception, WHITELEGGE'S species differ from those of Mr. GARDINER.

GENUS TURBINARIA, OKEN.

This genus makes its appearance in the Main Boring at the depth of 652 feet; below this to nearly the base of the boring it occurs sporadically, separated by long intervals. The casts are too imperfect for specific determination. Both J. S. GARDINER‡ and C. HEDLEY§ call attention to the marked absence of the genus in the recent fauna of Funafuti, but in a small collection of corals made by Professor SOLLAS from this locality, there were fragments of cup-shaped examples of *Turbinaria*, which indicate that it still exists on the atoll.

GENUS ASTRÆOPORA, BLAINV.

In the Main Boring this genus occurs at a depth of 88 feet, and next below this at 650 feet. It is occasionally met with from this level down to 1030 feet. It is

* 'Zool. Soc. Proc.,' 1898, pp. 257–262.
† Mem. III., Austral. Mus., Sydney, 1898, pp. 356–360.
‡ *Loc. cit.*, p. 262.
§ *Loc. cit.*, p. 350.

also present in the Lagoon Boring. Mr. J. S. GARDINER* states that it is fairly abundant in the lagoon at Funafuti.

GENUS MONTIPORA, QUOY and GAIMARD.

This genus is represented in all the borings, usually in the form of undulating layers of varying thickness, which grow horizontally over the surfaces of other corals. It occurs very sparsely in the Main Boring to the level of 775 feet; below this it is somewhat more frequent, but not sufficiently well preserved for specific identification. Six recent species are recorded by J. S. GARDINER† from the lagoon and outer reef at Funafuti.

GENUS PORITES, LAM.

Next after *Madrepora*, this genus is the most abundant of the corals in the Funafuti borings. It is met with throughout the Main Boring, but sparsely and at long intervals till reaching the level of 645 feet. From 870 feet to the bottom of the boring it is generally present; some of the cores principally consist of it, apparently in its position of growth. The largest massive specimen found, at 970 feet from the surface, has a vertical diameter of 325 millims. (13 inches). Only one species, *P. arenosa*, ESPER, has been identified. *Porites* is also present in the Second Boring (D) and in the lower part of the Lagoon Boring. Mr. J. S. GARDINER‡ has described eight recent species and varieties of this genus (including *P. arenosa*), most of them new forms; with one exception these lived on the shoals of the lagoon at Funafuti.

GENUS GONIOPORA, QUOY and GAIMARD.

Fragments of this genus have been met with in the lower part of the Lagoon Boring. It has not been found in the other borings, nor has it been noticed in the recent fauna of Funafuti.

Undetermined Corals.

In addition to the above, there are many casts of corals in the cores, more particularly in those from the lower part of the Main Boring, the condition of which is so unfavourable, owing to dolomitisation and other causes, that their generic characters could not be determined. All that can be distinguished is whether they are aporose or perforate forms.

(70) NOTES ON VARIOUS ORGANISMS AND ON CALCAREOUS ALGÆ FROM THE FUNAFUTI BORINGS.

SPONGES.

No specimens of either siliceous or calcisponges have been noticed in the boring materials, but siliceous boring sponges belonging to *Cliona* and allied genera must

* 'Zool. Soc. Proc.,' 1898, p. 263.

† *Ibid.*, pp. 265–267.

‡ *Ibid.*, pp. 267–276.

greater part of the rock, and between 652–660 feet in the Main Boring they are the main constituents of the cores. As a rule their structure is well-preserved, so that they are readily recognised in microscopic sections. The specimens in the Lagoon Boring have been determined by Miss BARTON* (Mrs. GEPP) to belong to *H. opuntia*, LAM., var. *macropus*, ASKENASY. According to Mr. FINCKH, *Halimeda* is remarkably abundant both on the present floor of the lagoon and on the ocean slopes of the reef at Funafuti.

GENUS LITHOTHAMNION, PHILIPPI.

This genus is represented in the different borings by branching, nodular, and more especially by encrusting forms, which grow over corals and other organisms so as to form layers of very compact dense rock. In many parts of the borings, particularly between 730–1100 feet of the Main Boring, *Lithothamnion* materially contributes to the cores. In the recent examples of calcareous algæ from Funafuti, Professor FOSLIE distinguishes, besides *Lithothamnion*, two other allied genera, *Lithophyllum* and *Goniolithon*, but in the fossil forms enclosed in the solid cores it has not been practicable to recognise the distinctive characters of the two latter genera, and they have therefore been all placed under *Lithothamnion*.

(8) SUMMARY.

Of the borings carried out at Funafuti with the object of investigating the structure of a coral reef, the most important is that known as the Main Boring, which reached a depth of 1114½ feet. The two earlier borings, which had to be abandoned after reaching 105 feet and 75 feet respectively, were practically similar to the corresponding depths of the Main Boring. The two borings in the lagoon, situated near each other, penetrated to 113 feet and 144 feet *below* the floor of the lagoon, the depth of water at the spot being 101 feet.

In the Main Boring, for a distance of 748 feet from the surface or about two-thirds of its depth, the greater part of the rock passed through was either unconsolidated or so lightly cemented that in the process of drilling about nine-tenths of it was reduced to granular and powdery fragmental material and the remaining tenth was solid hard limestone. The lower third of the boring, from the level of 748 feet to the bottom at 1114 feet, consisted almost entirely of dolomite or dolomitic limestone sufficiently hard to yield a practically continuous solid rock-core, with a total length of 311 feet, or 85 per cent. of the distance passed through. The rock throughout the boring is either limestone or dolomitic in character; no silica has been observed, and there are no traces of pumice or other volcanic products. The rock cores do not show any distinct evidence of stratification.

The rock appears to be entirely of organic derivation, consisting principally of the skeletal remains of corals and foraminifera with calcareous algæ belonging to

* 'Linnæan Soc. Journ.,' Botany, vol. 34, 1900, p. 481.

Halimeda and *Lithothamnion*. With these are commingled, mostly in a fragmentary condition, the spines and test plates of echinids, annelid tubes, crustacean tests, polyzoa, ascidian spicules, sponge spicules and the shells or casts of lamellibranchs and gastropods. These fragmentary remains are embedded in a calcareous sediment of minute organic particles and amorphous material, which fills up the interspaces of the corals and other organisms, and the whole mass is cemented by either crystalline carbonate of lime or dolomite. In places the crystalline cement is only slightly developed, and the organic *débris* then readily breaks up into its constituent elements. After consolidation many of the smaller organic particles have been dissolved, leaving the rock porous, and larger cavities have been produced by the removal of corals by solution. The corals, unfortunately, have suffered greater alteration in the fossilisation than any of the other organisms in the rock. From the surface to the depth of about 180 feet, the structural change has not been great, but they are often obscured by the infilling of their interstices with fibrous crystalline material; at greater depths the coral walls and other structures have been dissolved and removed, and only casts in sedimentary or crystalline materials remain.

The construction of the rock is best shown in the solid cores from the upper part of the boring to the depth of 150 feet, and in the lower third, from 750 feet to the bottom. The solid cores, in the upper portion, to a large extent consist of masses of coral—*Millepora*, *Heliopora*, *Pocillopora*, and *Madrepora*—in their positions of growth and often overgrown by *Lithothamnion*, but not much changed, otherwise than by the infiltration referred to above. The interspaces between the corals are filled with foraminifera, fragmentary organisms and sediment, and these materials also compose the softer, incoherent portions of the rock, which in this part of the boring comprise five-sixths of the whole. Allowing for coral fragments amongst the *débris*, the proportion of strictly coral rock would not be more than one-fifth.

In the 350 feet of the lower part of the boring, where the rock cores are nearly continuous, and the corals, now in the condition of casts, are more numerous and varied than nearer the surface, there is a similar disposition of layers mainly of coral, alternating with layers mainly of foraminifera and fragmentary organic materials. There is no sharp boundary between these alternating layers, they gradually merge into each other. In contrast to the incoherent foraminiferal and fragmental layers of the higher part of the boring, these layers are here cemented by crystalline dolomite, and they are harder and more compact than the coral layers. These latter form a larger proportion of the whole rock than in the higher beds, but even here they appear to be considerably exceeded by the foraminiferal and fragmentary rocks.

In that portion of the Main Boring between 150 feet and 748 feet, the greater part of the rock has broken up into granular particles, and only about 8 per cent. of it has reached the surface as solid cores of limestone. Both the cores and the

fragmentary materials largely consist of foraminifera and organic *débris*, with only a small proportion of corals. As mentioned above, the corals in the boring below 180 feet have been greatly altered and reduced to mere casts, some of which are so friable that they can be crushed between the fingers. Fragments of such casts are present in the broken-up rock, and it seems highly probable that the fragile nature of the rock in this part of the boring may result from the destructive changes in the corals. But judging from the solid cores which have been preserved, the foraminifera and fragmental organic *débris* would form a still greater proportion of the rock than in the 150 feet above. The rock of the lower part of this division between 640 feet and 748 feet is generally friable, porous, and chalky-looking, coral casts are more numerous in it, *Halimeda* is abundant, and the cementing material is dolomite, thus showing a gradual passage into the rock below.

The corals recognised belong to twenty-eight genera; with one exception they are present in this Main Boring. They all belong to well-known reef-building forms, and most of them still exist on the reef and in the lagoon at Funafuti. Of the foraminifera forty-one genera have been determined, thirty-five of which occur in the Main Boring. Only seven of these genera are of significance as rock formers, and, like the corals, they are still flourishing on the present reef or in the lagoon.

Although there are considerable differences in the character of the rock in different parts of the Main Boring, the evidence appears to me to indicate a continuous formation of reef rock, without any abrupt break, from the depth of 1114 feet to the present time.

In the borings beneath the floor of the lagoon, the rock for a distance of about 70 feet consisted principally of the joints of *Halimeda* with a small proportion of foraminifera; these materials were quite loose and not cemented together in any way. Between 70 feet and the bottom of the boring at 144 feet the rock is a rubbly limestone cemented by calcite, in which *Halimeda* diminishes and is replaced by corals and foraminifera of the same kinds as those in the upper part of the Main Boring. The organisms are, as a rule, well preserved, and their structures are, if anything, better shown than those at corresponding depths of the Main Boring.

fragmentary materials largely consist of foraminifera and organic *débris*, with only a small proportion of corals. As mentioned above, the corals in the boring below 180 feet have been greatly altered and reduced to mere casts, some of which are so friable that they can be crushed between the fingers. Fragments of such casts are present in the broken-up rock, and it seems highly probable that the fragile nature of the rock in this part of the boring may result from the destructive changes in the corals. But judging from the solid cores which have been preserved, the foraminifera and fragmental organic *débris* would form a still greater proportion of the rock than in the 150 feet above. The rock of the lower part of this division between 640 feet and 748 feet is generally friable, porous, and chalky-looking, coral casts are more numerous in it, *Halimeda* is abundant, and the cementing material is dolomite, thus showing a gradual passage into the rock below.

The corals recognised belong to twenty-eight genera; with one exception they are present in this Main Boring. They all belong to well-known reef-building forms, and most of them still exist on the reef and in the lagoon at Funafuti. Of the foraminifera forty-one genera have been determined, thirty-five of which occur in the Main Boring. Only seven of these genera are of significance as rock formers, and, like the corals, they are still flourishing on the present reef or in the lagoon.

Although there are considerable differences in the character of the rock in different parts of the Main Boring, the evidence appears to me to indicate a continuous formation of reef rock, without any abrupt break, from the depth of 1114 feet to the present time.

In the borings beneath the floor of the lagoon, the rock for a distance of about 70 feet consisted principally of the joints of *Halimeda* with a small proportion of foraminifera; these materials were quite loose and not cemented together in any way. Between 70 feet and the bottom of the boring at 144 feet the rock is a rubbly limestone cemented by calcite, in which *Halimeda* diminishes and is replaced by corals and foraminifera of the same kinds as those in the upper part of the Main Boring. The organisms are, as a rule, well preserved, and their structures are, if anything, better shown than those at corresponding depths of the Main Boring.

fragmentary materials largely consist of foraminifera and organic *débris*, with only a small proportion of corals. As mentioned above, the corals in the boring below 180 feet have been greatly altered and reduced to mere casts, some of which are so friable that they can be crushed between the fingers. Fragments of such casts are present in the broken-up rock, and it seems highly probable that the fragile nature of the rock in this part of the boring may result from the destructive changes in the corals. But judging from the solid cores which have been preserved, the foraminifera and fragmental organic *débris* would form a still greater proportion of the rock than in the 150 feet above. The rock of the lower part of this division between 640 feet and 748 feet is generally friable, porous, and chalky-looking, coral casts are more numerous in it, *Halimeda* is abundant, and the cementing material is dolomite, thus showing a gradual passage into the rock below.

The corals recognised belong to twenty-eight genera; with one exception they are present in this Main Boring. They all belong to well-known reef-building forms, and most of them still exist on the reef and in the lagoon at Funafuti. Of the foraminifera forty-one genera have been determined, thirty-five of which occur in the Main Boring. Only seven of these genera are of significance as rock formers, and, like the corals, they are still flourishing on the present reef or in the lagoon.

Although there are considerable differences in the character of the rock in different parts of the Main Boring, the evidence appears to me to indicate a continuous formation of reef rock, without any abrupt break, from the depth of 1114 feet to the present time.

In the borings beneath the floor of the lagoon, the rock for a distance of about 70 feet consisted principally of the joints of *Halimeda* with a small proportion of foraminifera; these materials were quite loose and not cemented together in any way. Between 70 feet and the bottom of the boring at 144 feet the rock is a rubbly limestone cemented by calcite, in which *Halimeda* diminishes and is replaced by corals and foraminifera of the same kinds as those in the upper part of the Main Boring. The organisms are, as a rule, well preserved, and their structures are, if anything, better shown than those at corresponding depths of the Main Boring.

TABLE showing the Distribution of Genera of

N.B.—The figures in the columns indicate the number of the particular rock-core in which the organism occurs ;

Depth from surface in feet.	Nos. of cores.	Nubecularia = Nb. Spiroloculina = Sp.	Miliolina = Ml. Ophthalmidium = Op. Peneroplis = Pen.	Orbitolites.	Alveolina = Al. Sagenina = Sg. Placopsilina = Pl.	Bdelloidina = Bd. Haddonia = Hd. Textularia = Tx.	Gaudryina = Gy. Valvulina = Val.	Bolivina = Bl. Marginulina = Mg. Cristellaria = Cr. Sagrina = Sn.	Globigerina.
0– 10	1– 11	Nb. 3		1–5, 8		Hd. 4			
10– 20	12– 18			17, 18					
20– 30	19– 33			21, 26, 32	Pl. 28				26
30– 40	34– 55			34, 39–47, 49–51	Pl. 49–51				
40– 50	56– 59								
50– 60	60– 67								
60– 70	68– 84		Ml. 74	74		Tx. 74		Cr. 74 Sn. 74	
70– 80	85– 93			85–87, 89, 90					
80– 90	94–100		Ml. 100	100					100
90–100	101–108		Ml. 108	102					
100–110	109–115			110, 114					
110–120	116–120								
120–130	121–129	Sp. 129		121, 127					
130–140	130–134			132, 133					
140–150	135–137								
150–160	138–141			141		Tx. 141		Cr. 141	141
160–170	142–143								
170–180	144–150			144, 145		Tx. 144, 145			144, 145
180–190	151–158								158
190–200	159–175								159, 166
200–210	176–178								178
210–220	179–185			183					180
220–230	186			186					
230–240	187–188			188					
240–280	189–198			189, 191–198		Tx. 193–197		Mg. 191	192
280–290	No solid cores								
290–300	„			×					×
300–310	„								
310–320	„			×					
320–330	„								
330–340	„							Bl. ×	
340–350	„	Nb? ×							×
350–360	„								
360–370	„								
370–373	„								
373–378	199–206			199, 200 202–206		Tx. 204			200
378–410	No solid cores			×					
410–420	207–213	Sp. ×		207–212		Tx. 212			
420–433	214–222			215, 217					
433–450	No solid cores								
450–457	223–229								226
457–468	230–233			233		Tx. 233			
468–480	234–236			234					
480–497	237–241		Ml. 240	240					
497–505	242–252		Ml. 243	243					
505–517	253–258		Ml. 255, 258	255, 258		Tx. 258			
517–526	259–267			259, 260					
526–546	268–289								

Foraminifera in the Cores of the Main Boring, Funafuti.

where the organism is found in samples of loose materials without numbers, its presence is marked by a cross.

Spirillina = Sr. Cymbalopora = Cy. Discorbina = Ds.	Planorbulina = Pb. Truncatulina = Tn. Anomalina = An.	Carpenteria.	Pulvinulina = Pul. Rotalia = Rl. Calcarina = Cl.	Tinoporus = Tp. Gypsina = Ga.	Polytrema.	Nonionina = No. Polystomella = Ps.	Amphistegina Lessonii.	Heterostegina depressa.	Cycloclypeus Carpenteri.
				Tp. 1-3, 5,7, 8	1-5, 7, 8, 9-11		1-3, 7, 8		
				Ga. 5					
		16			12, 13, 15-18				
		24			20-26, 32				
	Pb. 49-51	36, 39-47,			34, 36-39, 42,				
		49-51			49-51, 54				
		58			56				
		62		Ga. 62	61				
Sr. 74, 84	Tn. 74	68	Pul. 84	Ga. 74, 84	68, 70-73, 74,		74, 84	74, 84	
Ds. 74					84				
		85-87, 90-92		Ga. 89	85-87, 89, 90		85-87, 89, 90	89, 90	
	Tn. 100	100	Rl. ? 100	Ga. 100	100		96, 100	100	
				Tp. 102	108		101, 102, 108	102, 108	
		110, 114		Ga. 110.	110		109, 110, 112		
							115		
							118, 120		
		123, 124		Tp. 121, 123,	123, 124		121-129		
				124, 126					
		132		Tp. 132	132, 133	No. 134	132, 134		
				Ga 134					
		135			135		135		
Ds. 141	Tn. 141	141		Tp. 138	141		138, 141	141	
	Pb. 141			Ga 141					
	An. 143	143		Tp. 142, 143	143		142, 143		
				Ga 143					
Ds. 144, 145	Tn. 144, 145	144, 145			144, 145		144-147, 149	144, 145	
	Tn. 151	158		Ga. 158	158		151, 158		
Ds. 159	Tn. 159	159		Ga. 159	159, 166		159, 166, 175	159	
					178		178		
Cy 183		180, 183, 185		Ga. 180	180, 183, 185		180, 181, 183	180	
	Tn. 186	186			186		186		
			Cl. 188	Ga. 187			187, 188		
Cy. 190	Tn. 198	189, 193-197	Cl. 189,	Tp. 189	189, 197, 198		189-198	189-191,	
Ds. 196, 198			193-197	Ga. 193-198				192, 197	
							×		
		×			×	No. ? ×		×	
							×		
							×		
		×			×		×		
			Cl. ×				×		
		×			×		×		
							×		
Ds. ×	An. ×		Cl. ×				×		
		×	Cl. ×	Tp. ×	×		×		
	Tn. 205	200, 205	Cl. 200, 204	Ga. 200, 205	200, 204, 205		199-206	205	
			205						
		×	Cl. ×				×	×	
		207, 212	Cl. 207, 212	Ga. 207	207, 212		207-212	212	
			Cl. 215, 217		215		214		
			Cl. ×	•					
		229	Cl. ×		226, 229	No. ×	223		
		230, 233	Pul. 233		233		220	230	
							238, 239		
		240		Ga. 240	240				
		243			243				
		255, 258		Ga. 255, 258	255, 258		253, 255, 258	255, 258	
	Tn. 267	261, 263, 267	Cl. 267	Ga. 263, 267	263, 267		259, 260,	263	
							263-265, 267		
		269, 274, 284		Ga. 269, 284	269, 274, 284		269, 271-274,		
							284		

TABLE showing the Distribution of Genera of Foraminifera

Depth from surface in feet.	Nos. of cores.	Nubecularia = Nb. Spiroloculina = Sp.	Miliolina = Ml. Ophthalmidium = Op. Peneroplis = Pen.	Orbitolites.	Alveolina = Al. Sagenina = Sg. Placopsilina = Pl.	Bdelloidina = Bd. Haddonia = Hd. Textularia = Tx.	Gaudryina = Gy. Valvulina = Val.	Bolivina = Bl. Marginulina = Mg. Cristellaria = Cr. Sagrina = Sn.	Globigerina.
546–555	290–296			294, 296					
555–567	No solid cores								
567–578	296a–296b					Tx. 296a			296a
578–598	297–304		Ml. 304					Bl. 304	304
598–612	305–306								305, 306
612–624	No solid cores								
624–637	307–312		Ml. 307–309						307–309
637–643	313–320	Sp. 320	Ml. 314	320		Tx. 318, 320			320
643–652	321–335	Sp. 334	Ml. 328, 334, 335						329–331, 332, 334
652–660	336–343		Ml. 336	336–338, 340, 341		Tx. 341			342, 343
660–670	344–347			346	Al. ? 345	Tx. 346, 347			344, 346, 347
670–691	348–356								348–352, 354, 355
691–698	357–366			364		Tx. 361			357, 359–361, 363–366
698–706	1A–2A								
706–716	3A–8A								
716–736	9A–16A				Al. 13A, 14A–16A				11A, 12A, 14A, 16A
736–748	17A–31A			22A, 25A	Al. 21A, 22A	Bd. 25A			22A, 25A
748–763	32A–54A	Sp. 42A		45A–54A		Hd. 36A Tx. 45A, 16A			40A ?, 45A, 46A, 51A
763–771	55A–73A			55A, 56A, 58A 60A, 61A					59A, 63A
771–781	74A–96A			75A, 86A					
781–790	97A–122A			101A, 105A, 106A, 108A, 110A, 112A, 113A, 120A	Pl. 114A, 115A	Tx. 101A, 112A, 115A			
790–798	123A–144A			126A–128A, 133A, 138A–140A		Tx. 135A			
798–804	145A–156A								
804–810	157A–174A			161A		Tx. 174A			161A
810–815	175A–186A		Op. 183A	181A–183A, 185A					
815–822	187A–197A			187A					197A
822–833	198A–215A								203A, 204A
833–844	216A–234A	Sp. 224A		216A, 218A, 219A, 220A–227A, 229A, 234A		Tx. 224A			217A
844–853	235A–248A			235A					246A
853–866	249A–276A		Pen. 250A	258A, 262A				Bl. 267A	250A, 258A
866–874	277A–296A			287A, 294A–296A					282A 283A

TABLE showing the Distribution of Genera of Foraminifera

Depth from surface in feet.	Nos. of cores.	Nubecularia = Nb. Spiroloculina = Sp.	Miliolina = Ml. Ophthalmidium = Op. Peneroplis = Pen.	Orbitolites.	Alveolina = Al. Sagenina = Sg. Placopsilina = Pl.	Bdelloidina = Bd. Haddonia = Hd. Textularia = Tx.	Gaudryina = Gy. Valvulina = Val.	Bolivina = Bl. Marginulina = Mg. Cristellaria = Cr. Sagrina = Sn.	Globigerina.
874–881	297A–310A			297A–310A		Tx. 309A			
881–890	311A–325A			311A–325A					
890–899	326A–340A			326A, 329A–333A		Tx. 329A, 336A, 337A			
899–910	341A–353A			342A 352A		Tx. 345A			
910–922	354A–376A			362A–364A, 366A–376A					
922–936	377A–404A		Ml. 377A–379A Ml. 388A, 289A	380A–382A, 388A, 389A, 396A, 397A, 400A–403A		Hd. 388A, 389A, 398A, Tx. 396A, 400A, 401A			398A, 399A
936–945	405A–421A			407A–416A, 421A					
945–957	422A–442A			422A–433A, 436A–442A					425A, 427A
957–963	443A–449A			443A–449A					
963–973	450A–470A			450A–464A, 470A	Pl. 470A	Tx. 456A, 457A, 470A			
973–983	471A–490A			476A–479A, 481A–490A		Hd. 476A–479A Hd. 481A–484A			
983–991	491A–507A			491A–507A		Tx. 491A, 494A			
991–1006	508A–527A			508A–520A, 523A–527A					
1006–1015	528A–542A		Ml. 557A, 538A	533A, 536A–542A			Val. 534A Gy. 537A, 538A		
1015–1025	543A–564A			543A–564A		Tx. 562A–564A			
1025–1034	$565A–583A_1$			565A–568A, $573A–583A_1$					
1034–1044½	$583A_2$–594A		Ml. 590A	$583A_2$–585A, 588A–594A		Tx. 584A, 590A			
1044½–1053	595A–607A			595A–606A					
1053–1066	608A–627A			608A, 611A–627A		Tx. 618A–620A			618A–620A
1066–1075	628A–643A			628A–643A		Tx. 628A			
1075–1087	644A–661A			644A, 646A, 648A, 655A		Tx. 659A			
1087–1100	662A–682A		Ml. 675A	665A–672A, 675A, 677A, 678A, 680A, 681A		Tx. 665A, 675A, 677A			675A
1100–1114½	683A–709A		Ml. 701A, 703A 705A	683A, 684A, 687A–709A		Tx. 695A, 701A, 705A, 709A			701A

in the Cores of the Main Boring, Funafuti—*continued.*

Spirillina = Sr. Cymbalopora = Cy. Discorbina = Ds.	Planorbulina = Pb. Truncatulina = Tn. Anomalina = An.	Carpenteria.	Pulvinulina = Pul. Calcarina = Cl.	Gypsina.	Polytrema.	Nonionina = No. Polystomella = Ps.	Amphistegina Lessonii.	Heterostegina depressa.	Cycloclypeus Carpenteri.
	Pb. 306A, 309A	306A, 309A	Cl. 308A, 309A	304A, 309A	306A, 307A, 309A, 310A	No. 306A	297A–300A, 301A–310A	309A	
	Pb. 321A	314A–317A, 319A–321A	Cl. 311A, 321A	312A, 319A	314A–325A	No. 319A, 320A	311A, 312A, 314A, 315A, 318A–325A	312A, 321A	
		330A	Cl. 329A, 337A	337A	327A–340A		329A–337A, 340A	329A, 336A, 337A	
		347A	Cl. 342A–345A	342A–346A	341A–353A		341A–347A, 350A	342A–346A, 352A	
	Pb. 363A, 364A	362A–372A	Cl. 364A, 372A, 373A	364A, 372A, 373A	354A–372A, 376A		357A, 362A–364A, 366A, 367A, 373A–376A	360A, 364A, 372A, 373A	
	Pb. 398A, 399A	377A–379A, 383A, 398A–401A		377A–379A, 388A, 389A, 400A, 401A	377A–390A, 396A, 397A, 400A–404A		377A–381A, 386A–389A, 391A, 394A, 395A, 397A, 402A–404A	377A–382A, 388A, 389A, 398A	
		407A, 412A–416A, 418A–420A		405A, 406A	405A–411A, 415A, 417A		405A–421A	405A, 406A	
		422A–425A, 427A, 436A–441A	Cl. 424A, 427A	424A, 427A	424A–433A		422A–438A	424A, 425A, 438A	
		443A, 445A–449A		443A	443A–449A		443A–149A	443A, 445A–448A	
		450A–461A, 470A		470A	450A–453A, 456A–466A, 470A		450A–470A	455A–461A	
		476A–484A, 487A–490A		487A–490A	471A–479A		471A–490A	476A–488A	
		491A–494A, 497A	Cl. 491A–494A	502A–504A	491A–494A, 498A–507A		491A–507A	491A–504A	
					523A–527A		508A–521A, 523A–527A		
		534A, 537A, 538A		534A	528A–540A		528A–534A, 536A–538A, 541A, 542A	534A	
		560A–564A	Pul. 562A–564A	551A–553A, 557A–559A, 562A–564A	554A–564A		543A–564A		
		566A–570A, 573A–582A		573A–582A	565A, 571A, 572A		565A–583A$_1$	573A–582A	
			Cl. 590A, 593A, 594A	584A, 585A, 590A–594A	584A–587A, 590A–594A		583A$_2$–587A, 590A–594A	584A, 587A	584A 590A
	Pb. 606A	606A		595A, 598A–600A, 602A, 603A	595A–607A		595A–607A	595A, 603A, 606A	
	Pb. 611A–622A	618A–621A, 623A	Cl. 618A–621A, 623A–625A	608A–621A, 623A–627A	608A–627A		608A–627A	611A–627A	
		629A, 639A, 640A		628A, 629A, 639A, 640A	628A–640A, 642A, 643A		628A–643A	630A–640A	639A
	Pb. 646A–648A	644A	Pul. 646A Cl. 646A	644A, 646A,	644A, 646A–648A, 650A–652A, 655A, 656A		644A, 646A–649A, 653A–658A	648A	
	Pb. 677A–681A	675A, 677A, 681A	Cl. 665A, 675A, 682A	665A, 675A–677A, 681A	662A–664A, 668A, 671A, 675A–682A		662A–682A	671A, 675A, 677A	
	Pb. 695A, 701A	699A–701A, 703A, 707A, 709A	Cl. 703A, 707A	699A–701A, 703A, 705A, 709A	683A–709A		683A–686A, 689A–709A	703A, 705A, 708A	

TABLE showing the Distribution of Genera of Foraminifera

Depth from surface in feet.	Nos. of cores.	Nubecularia = Nb. Spiroloculina = Sp.	Miliolina = Ml. Ophthalmidium = Op. Peneroplis = Pen.	Orbitolites.	Alveolina = Al. Sagenina = Sg. Placopsilina = Pl.	Bdelloidina = Bd. Haddonia = Hd. Textularia = Tx.	Verneuilina = Ver. Gaudryina = Gy. Valvulina = Val.	Bolivina = Bl. Marginulina = Mg. Cristellaria = Cr. Sagrina = Sn.	Globigerina.
0– 30	C. 1–C. 5_1	Nb. C. 4	Ml. C. 4	C. 2–C. 4, C. 5_1	Pl. C. 4	Hd. 5_1			
30– 50	C. 6–C. 15	Nb. C. 9, C. 12	Ml. C. 6	C. 6, C. 10–C. 12			Val. C. 10		
50– 80	C. 16–C. 22			C. 19, C. 20, C. 22					
80– 85	C. 23–C. 28			C. 23					
85–105	C. 29–C. 36		Ml. ×	C. 31		Tx. ×	Ver. ×		

TABLE showing the Distribution of Genera of Foraminifera

Depth from surface in feet.	Nos. of cores.	Nubecularia = Nb. Spiroloculina = Sp.	Miliolina = Ml. Cornuspira = Cor. Peneroplis = Pen.	Orbitolites.	Alveolina = Al. Sagenina = Sg. Placopsilina = Pl.	Bdelloidina = Bd. Haddonia = Hd. Textularia = Tx.	Verneuilina = Ver. Gaudryina = Gy. Valvulina = Val.	Bolivina = Bl. Marginulina = Mg. Cristellaria = Cr. Sagrina = Sn.	Globigerina. Pullenia = Pla.
0–12									
12–20	D. 1–D. 4								
20–30	D. 5–D. 10								
30–40	D. 11–D. 17	Sp. ×	Ml. × Cor. ×					Bl. × Cr. × Sn. ×	
40–50	D. 18–D. 35								
50–60	D. 36–D. 57			D. 39, D. 51, D. 57					
60–72	D. 58–D. 74		Cor. ×	D. 65, D. 72, D. 74 ×				Sn. ×	× Pla. ×

in the Cores of the First Boring (C), Funafuti.

Spirillina = Sr. Cymbalopora = Cy. Discorbina = Ds.	Planorbulina = Pb. Truncatulina = Tn. Anomalina = An.	Carpenteria.	Pulvinulina = Pul. Calcarina = Cl.	Tinoporus = Tp. Gypsina = Ga.	Polytrema.	Nonionina.	Amphistegina Lessonii.	Heterostegina depressa.	Cycloclypeus Carpenteri.
				Ga. C. 4	C. 2–C. 4, C. 5_1		C. 2, C. 4		
	Pb. C. 9	C. 6, C. 7?, C. 9, C. 12*		Ga. C. 6, C. 9, C. 10, C. 12	C. 6–C. 10, C. 13		C. 6		
Ds. C. 19	Pb. C. 22	C. 19			C. 16, C. 19–C. 22		C. 19, C. 21, C. 22		
		C. 24		Ga. C. 23, C. 28	C. 25–C. 27	C. 23?			
	Tn. ×	×	Pul. × Cal. ×	Ga. ×			C. 31, ×	×	

in the Cores of the Second Boring (D), Funafuti.

Spirillina = Sr. Patellina = Pt. Cymbalopora = Cy. Discorbina = Ds.	Planorbulina = Pb. Truncatulina = Tn. Anomalina = An.	Carpenteria.	Pulvinulina = Pul. Calcarina = Cl.	Tinoporus = Tp. Gypsina = Ga.	Polytrema.	Nonionina.	Amphistegina Lessonii.	Heterostegina depressa.	Cycloclypeus Carpenteri.
		D. 2	Cl. D. 2		D. 1, D. 3 D. 8		D. 2		
Sr. ×, Cy. ×, Pt. ×, Ds. ×		D. 15, ×	Pul. × Cl. ×	Tp. ×	D. 15–D. 17 ×		×		
					D. 22, D. 23, D. 28, D. 29, D. 31, D. 34		D 22, D. 25		
				Ga. D. 51	D. 45, D. 51, D. 57				
Sr. × Ds. ×	Pb ×	D. 74	Pul. × Cl. ×	Tp. ×	D. 58, D. 59, D. 63, D. 65–D. 67, D. 72, D. 74 ×		D. 61, D. 66 ×	×	

TABLE showing the Distribution of Genera of Foraminifera

Depth from floor of lagoon in feet.	Nos. of samples.	Nubecularia = Nb. Spiroloculina = Sp.	Miliolina = Ml. Cornuspira = Cor. Peneroplis = Pen.	Orbitolites.	Alveolina = Al. Sagenina = Sg. Placopsilina = Pl.	Bdelloidina = Bd. Haddonia = Hd. Textularia = Tx.	Verneuilina = Ver. Gaudryina = Gy. Valvulina = Val.	Bolivina = Bl. Marginulina = Mg. Cristellaria = Cr. Sagrina = Sn.	Globigerina.
21½	L. 2	Sp. ×			Sg. × Pl. ×	Tx. ×	Val. ×	Sn. ×	×
35½	L. 3					Hd. ×			
50	L. 4	Sp. ×	Ml. ×	×	Sg. × Pl. × ?	Bd. × ? Tx. ×		Sn. ×	
62	L. 5	Sp. ×	Ml. ×	×	Sg. × Pl. ×	Tx. ×		Sn. ×	×
75	L. 6		Ml. ×	×		Tx. ×			
81½– 82	L. 7, L. 16			×	Sg. ×	Hd. × Tx. ×			
94¼	L. 8					Tx. ×			
103½–105	L. 9, L. 15								
106¾	L. 11, L. 12								
112½	L. 10								
116 –144	L. 13–L. 14E		Ml. ×			Tx. ×			×

TABLE showing the Distribution of Coral Genera

Depth from surface in feet.	Nos. of cores.	Millepora. Stylaster = Sta.	Alcyonarian Spicules. Lobophytum = Lo.	Heliopora cærulea.	Stylophora = Sty. Seriatopora = Ser.	Pocillopora.	Cœloria.	Astræa.	Goniastræa = Go. Prionastræa = Pr.
0– 10	1– 11	1, 2, 3, 6	Lo. 3	1–3, 5, 7, 8–11				5, 6	
10– 20	12– 18			13–16		12, 14			
20– 30	19– 33			19, 21–31, 33					
30– 40	34– 55	35, 36, 38, 39–48, 55		34, 35, 38–51, 54–55	Sty. 39–51	37, 54			
40– 50	56– 59		56		Sty. 56, 57	56			
50– 60	60– 67							64	
60– 70	68– 84			77					
70– 80	85– 93	Sta. 90							
80– 90	94–100			97, 98		100			
90–100	101–108		101, 102, 108	102, 108		103, 104, 106			
100–110	109–115		109, 115	109		113		111	
110–120	116–120	120	118			118			
120–130	121–129	121, 122, 123, 125				121–128			
130–140	130–134		Lo. 132, 134			130			
140–150	135–137								
150–160	138–141		138						
160–170	142–143	143	142, 143			143			
170–180	144–150		144, 145 Lo. 146						
180–190	151–158		Lo. 151, 152, 156		Sty. 157	158			
190–200	159–175			160–173	Sty. 170				
200–210	176–178	176?		178					Go. 178

in the Boring below the Floor of the Lagoon, Funafuti.

Spirillina = Sr. Cymbalopora = Cy. Discorbina = Ds.	Planorbulina = Pb. Truncatulina = Tn. Anomalina = An.	Carpenteria.	Pulvinulina = Pul. Calcarina = Cl.	Tinoporus = Tp. Gypsina = Ga.	Polytrema.	Nonionina = No. Polystomella = Ps.	Amphistegina Lessonii.	Heterostegina depressa.	Cycloclypeus Carpenteri.
	Tn. ×		Pul. ×	Ga. ×	×	No. ×	×	×	
	Pb. ×								
Ds. ×	Tn. ×		Cl. ×	Ga. ×	×		×	×	
	Pb. ×								
Sr. ×	Pb. ×	×	Pul. ×	Ga. ×	×	Ps. ×	×	×	
Ds. ×	Tn. ×		Cl. ×						
	An. ×								
			Cl. ×	Ga. ×	×	No. ×	×	×	
Sr. ×	Pb. ×		Pul. ×						
Ds. ×	Tn. ×		Cl. ×	Ga. ×	×		×	×	
	Tn. ×		Cl. ×			No. ×	×	×	
		×					×	×	
					×		×	×	
					×		×	×	
							×	×	
Ds. ×	Pb. ×		Cl. ×	Ga. ×	×		×	×	

in the Cores of the Main Boring, Funafuti.

Orbicella.	Hydnophora = Hy. Cyphastræa = Cy. Galaxea = Gx.	Astræan coral, genus uncertain.	Fungia = Fu. Cycloseris = Cs. Psammocora = Psa.	Halomitra = Hal.	Madrepora.	Montipora = Mt. Turbinaria = Tur.	Astræopora.	Porites.	Corals not determined. Aporosa = Ap. Perforata = Per.
					1-4, 9-11			8	Per. 5.
					13, 16			15 ?	
					32 ?				21, 22, 24
					52, 53, 55	Mt. 34, 35–37, 38 ?–47			Per. 54
					58, 59				
					60-62, 65-67	Mt. 63			
					68-76, 78,				74
					79-83.				Per. 79-81
					85-88, 91-93			89 ?	
96					94		99	94, 95 ?	
105								101, 107	
			Fu ? 110		112	Mt. 114			
					116	Mt. 119			
					121, 122–125				
					130, 131, 133				Ap. 132
					135-137				
					148			145	
									Per. 157
174 ?									

TABLE showing the Distribution of Coral Genera

Depth from surface in feet.	Nos. of cores.	Millepora. Stylaster = Sta.	Alcyonarian spicules. Lobophytum = Lo.	Heliopora cærulea.	Stylophora = Sty. Seriatopora = Ser.	Pocillopora.	Cœloria.	Astræa.	Goniastræa = Go. Prionastræa = Pr.
210–220	179–185		185			182, 184			
220–230	186					186			
230–240	187–188		187, 188			187, 188			
240–280	189–198		189–198		Sty. 197	189, 191–197			
280–290	No solid cores		×			×			
290–300	”					×			
300–310	”		×						
310–320	”	×	×			×			
320–330	”		×			×			
330–340	”					×			
340–350	”					×	×		
350–360	”					×			
360–370	”		×			×			
370–373	”					×			
373–378	199–206					200, 203			
378–410	No solid cores		×			×			
410–420	207–213		207 Lo. 212			211, 212	213		
420–433	214–222				Ser. 214, 216–222				
433–450	No solid cores					×			
450–457	223–229	224 ? 225 ?			Ser. 224–226	223, 227, 228			
457–468	230–233								
468–580	234–236								
480–497	237–241								
497–505	242–252								
505–517	253–258		253, 254, 258						
517–526	259–267		263, 267		Ser. 267	259–262, 266, 267			
526–546	268–289		269			269, 271–283	270, 284–289		Pr ? 274.
546–555	290–296		294					293 ?	
555–567	No solid cores								
567–578	296*a*–296*b*					×		296*a*	
578–598	297–304		304						
598–612	305–306					305		305	
612–624	No solid cores								
624–637	307–312				Sty. 312				
637–643	313–320		314, 316, 320			313			
643–652	321–335	325			Sty. 325, 333 Ser. 334	321–323			
652–660	336–343					340			
660–670	344–347					345			
670–691	348–356				Sty. 354				
691–698	357–366					359			
698–706	1A–2A								
706–716	3A–8A								
716–736	9A–16A								
736–748	17A–31A		31A						
748–763	32A–54A		36A, 43A, 45A, 54A			33A, 39A, 41A, 43A, 45A, 47A, 52A			
763–771	55A–73A				Ser. 59A	56A, 57A, 65A–67A		70A, 72A	Go. 59A ?, 61A–63A
771–781	74A–96A		83A, 84A, 86A, 94A			83A, 84A, 92A, 96A			

in the Cores of the Main Boring, Funafuti—*continued.*

Orbicella.	Hydnophora = Hy. Cyphastræa, = Cy. Galaxea = Gx.	Astræan coral, genus uncertain.	Fungia = Fu. Cycloseris = Cs. Psammocora = Psa.	Halomitra = Hal.	Madrepora.	Montipora = Mt. Turbinaria = Tur.	Astræopora.	Porites.	Corals not determined. Aporosa = Ap. Perforata = Per.
181									**Ap. 180**
								197 ?	**Per. 197**
								× ?	
									Per. ×
								× ?	
									Per. ×
									Per. ×
201 ?		200–202, 205, 206			200–203 205, 206			202	
								× ?	**Per. ×**
		207			207–213				
					217, 220–222				
									Per. ×
					224–229				
					237, 238, 240 ? 241				**Per. 240**
					243, 245–252				**Per. 242**
					255–258				
					259–262,	Mt. 259, 260			**264**
					265, 266				
		269, 270, 285–289		Hal. 2, 3 ?	268, 269, 271, 272, 275, 281– 283				
									Per. 293
					296*a*				**Per. ×**
		303	Fu. 297–301		304				
	Hy ? 318	332, 334	Fu ? 319		307, 308 314–317 323, 325–331, 333, 335		333	324 ? 326– 331, 334	**313, 320** **Per. 321, 322,** **328, 332**
339	**Cy. 337**		Fu. 338		336, 338, 342	Tur. 336, 338		337, 338, 340 ?	
			Fu. 344						**Per. 347**
		349, 354 360	Fu. 362 ? 363			Mt. 348, 351 ?		352 ?	**Per. 356** **361, 364**
					2A 4A 11A				
		10A	Cs. 9A 11A, 13A, 16A						
	Cy 28A.	23A, 24A	Cs. 26A, 27A, 29A, 31A						**Per. 28A**
37A–40A	Hy. 34A, 35A	44A, 50A–53A	Cs. 33A ? 52A		49A	Tur. 50A- 54A	41A ?	38A ?–40A, 45A–47A, 51A	**Per. 36A,** **42A, 45A, 49A**
	Gx. 60A ? Cy. 66A	56A, 58A, 67A	Cs. 56A Fu. 60A, 65A		55A–59A, 62A– 65A, 67A, 68A, 70A, 71A	Tur. 55A, 59A, 60A, Tur. 68A			**55A, 64A,** **Per. 69A,** **72A**
90A		92A–94A	Fu. 81A, 86A		82A, 85A 87A, 89A–92A, 95A, 96A	Mt. 86A, 95A, Tur. 93A			**74A–79A,** **82A, 85A,** **88A, 89A,** **90A**

Table showing the Distribution of Coral Genera

Depth from surface in feet.	Nos. of cores.	Millepora. Stylaster = Sta.	Alcyonarian spicules. Lobophytum = Lo.	Heliopora cærulea.	Stylophora = Sty. Seriatopora = Ser.	Pocillopora.	Cœloria.	Astræa.	Goniastræa = Go. Prionastræa = Pr.
781–790	97A–122A		102A, 104A, 105A, 107A, 112A, 115A			103A	104A, 108A–110A	121, 122A	Go. 112A, 115A
790–798	123A–144A		124A, 133A, 136A, 139A, 140A		Ser. 126A	133A, 138A–144A	124A ?	130A	
798–804	145A–156A					145A–156A			
804–810	157A–174A		165A, 168A, 173A, 174A		Ser. 169–171A	157A–159A, 161A, 163A, 168A, 169A–171A	162A		
810–815	175A–186A		176A, 177A, 183A, 184A						Go. 178A ?–183A ?
815–822	187A–197A	187A	187A					188A	
822–833	198A–215A				Sty. 207A ?	202A			
833–844	216A–234A	232A	217A, 222A, 224A, 226A, 229A		Sty. 223A				
844–853	235A–248A		235A, 236A			241A	.	237A	
853–866	249A–276A		251A, 258A					269A–271A	
866–874	277A–296A		281A–283A, 287A, 294A, 295A Lo. 289A			294A, 295A		282A–286A, 294A, 295A	Go. 294A, 295A
874–881	297A–310A		Lo. 301A 307A, 309A			299A–301A, 303A	300A, 302A, 304A–305A	300A ? 301A, 303A, 307A, 308A ?	Go. 305A
881–890	311A–325A	312A	Lo. 312A 312A		Ser. 311A	316A, 317A, 319A, 321A–323A	312A, 316A, 317A, 321A ?	311A, 312A, 318A ?	Go. 319A, 322A, 323A
890–899	326A–340A		Lo. 329A, 330A, 334A, 335A, 336A, 337A			327A, 328A, 338A, 339A	326A	327A ?	
899–910	341A–353A		342A–345A, 352A–353A Lo. 345A, 350A			348A		342A–346A, 352A	Go. 345A Pr. 346A
910–922	354A–376A		354A–357A, 374A–376A Lo. 362A			363A–369A	366A, 367A, 373A	357A, 359A, 368A, 369A	
922–936	377A–404A	398A, 399A–404A	388A–390A, 394A–397A Lo. 391A			383A, 396A, 398A–404A		392A–395A, 397A	
936–945	405A–421A	405A–407A	405A, 406A, 418A–420A		Ser. 408A	405A–412A	407A, 413A–416A	417A–420A	Pr. 412A ?, 417A

in the Cores of the Main Boring, Funafuti—*continued.*

Orbicella.	Hydnophora = Hy. Cyphastræa = Cy. Galaxea = Gx.	Astræan coral, genus uncertain.	Fungia = Fu. Cycloseris = Cs. Psammacora = Psa.	Siderastræa.	Madrepora.	Montipora = Mt Turbinaria = Tur.	Astræopora.	Porites.	Corals not determined. Aporosa = Ap. Perforata = Per.
		103A, 105A			97A–100A, 103A, 105A, 106A, 108A, 109A, 111A–118A, 120A		106A–108A	98A, 101A–103A	**Per. 99A–100A, 105A, 119A**
123A ?		134A			130A–136A–141A	Mt. 131A–133A		130A–133A	**126A–128A, 137A Per. 135A**
					145A–149A, 155A, 156A	Mt. 145A ?		145A	
		158A, 159A, 161A	Fu. 174A		157A, 162A–165A, 167A, 169A–171A, 174A	Mt. 161A ?, 163A ? Tur. 165A	163A		**Per. 158A, 159A, 174A**
		186A	Cs. 186A		175A, 178A, 184A, 186A	Mt. 178A, 182A	181A	175 ?, 183A, 186A	
					188A–190A		187A		**188A, 191A–193A, Per. 197A**
					199A ?, 205A, 206A, 208A ?, 210A–212A		213A		**198A, 206A, 209A Per. 201A, 214A, 215A**
213A ?		220A, 221A, 226A, 232A ?			223A, 226A, 231A, 232A		226A ?		**217A–222A, 226A, 233A, 234A**
238A ?		235A, 239A			236A, 238A, 239A	Mt. 241A			**235A, 238A, 240A Per. 243A, 245A, 246A–248A**
							260A ?		**Per. 249A, 261A, 268A–270A**
		277A–281A	Fu. 282A, 283A ?		294A, 295A			281A, 284A–293A, 296A	**Per. 292A–295A**
		310A	Fu. 303A		301A–304A, 309A, 310A	Tur. 307A	304A, 309A	299A–304A, 307A	**297A, 298A Per. 306A, 308A–310A**
			Fu. 316A ?, 317A ? Cs. 321A ?		311A–321A			313A–317A, 319A–321A	**Per. 311A, 324A, 325A**
					326A, 328A, 329A, 330A–335A		328A	327A–329A, 331A, 335A–340A	**329A**
	Gx. 347A, 353A				345A, 348A–350A, 352A	Mt. 341A, 345A	346A ?	341A, 345A–352A	**Per. 342A, 346A**
360A, 361A, 366A, 367A, 373A	Hy. 273A				354A–357A, 362A–367A, 370A–376A	Mt. 354A–357A, 359A, 362A–365A, 373A–376A		354A–361A, 363A–369A, 371A, 374A–376A	**360A–363A, 368A, 369A**
377A–379A		390A, 391A,			377A–381A, 391A, 394A–396A, 398A, 399A	Mt. 377A–379A, 398A, 399A, 402A, 403A		377A–379A, 382A, 384A–387A, 392A–395A, 397V–399A	**Per. 382A, 388A, 389A**
408A		405A–408A, 410A, 411A			407A–411A, 413A–416A, 418A–420A		418A–420A	407A–411A, 413A–416A, 418A–421A	

TABLE showing the Distribution of Coral Genera

Depth from surface in feet.	Nos. of cores.	Millepora. Stylaster = Sty.	Alcyonarium spicules. Lobophytum = Lo.	Heliopora cærulea	Stylophora = Sty. Seriatopora = Ser.	Pocillopora.	Cœloria. Euphyllia = Eu.	Astræa.	Goniastræa = Go. Prionastræa = Pr.
945–957	422A–442A	425A, 431A–433A, 438A	424A, 426A–433A Lo. 426A, 431A–433A, 436A, 441A			431A–435A, 437A–442A	428A–430A, 434A, 435A, 437A, 439A–441A	427A–433A	Pr. 422A, 423A, 430A–433A, 436A Go. 442A
957–963	443A–449A	443A	443A, 446A–448A			443A–444A, 446A–449A		446A–448A	
963–973	450A–470A	468A	453A–455A, 458A–468A, 470A Lo. 457A		Ser. 467A	450A–452A, 454A–455A, 467A, 468A	450A–452A, 456A, 470A	450A–452A	
973–983	471A–490A		471A–474A, 480A–484A			481A–484A	471A, 481A–484A	471A ?, 476A–479A	
983–991	491A–507A	505A–507A	491A–494A, 502A–504A				495A, 496A		
991–1006	508A–527A	508A–512A, 524A–525A	508A–510A, 519A, 520A, 523A, 524A–527A Lo. 508A, 523A		Ser. 510A–518A, 524A–527A Sty. 521A	510A, 521A, 523A	518A, 520A	513A–518A	Pr. 523A
1006–1015	528A–542A	528A, 535A	528A–538A		Sty. 536A, 539A–542A Ser. 528A–533A, 535A, 537A, 538A	533A, 535A, 537A–542A	533A–535A	535A	
1015–1025	543A–564A	546A, 556A	562A–564A		Sty. 543A–555A, 560A	543A–553A, 560A–564A	543A–546A	551A–553A, 554A, 560A	
1025–1034	565A–$583A_1$	569A–573A	565A–575A, 577A Lo. 571A		Sty. 579A–582A	566A–582A	569A–572A, 577A–582A	577A	Pr. 565A
1034–1044½	$583A_2$–594A	584A, 585A, 593A, 594A	584A, 590A, 593A, 594A		Sty. 585A, 586A, 588A, 591A, 593A, 594A Ser. 585A, 587A	$583A_2$–586A, 588A–594A	585A, 588A, 589A, 592A	$583A_2$, 584A	
1044½–1053	595A–607A	598A, 603A, 604A	598A–600A, 603A, 606A		Sty. 595A, 596A, 599A–602A, 604A–607A Ser. 597A–601A	595A, 596A, 598A, 604A–607A		601A, 603A, 606A	
1053–1066	608A–627A		611A–620A Lo. 619A, 622A, 623A		Sty. 608A, 610A, 622A–624A Ser. 623A	608A–610A, 622A, 623A, 627A			
1066–1075	628A–643A	628A, 634A, 636A	628A–643A		Sty. 628A, 636A, 640A	628A, 630A–638A	Eu. 641A		
1075–1087	644A–661A	644A, 649A, 657A	644A–646A		Sty. 648A, 650A–656A Ser. 648A, 649A, 653A, 659A	644A, 651A, 652A		655A, 656A	
1087–1100	662A–682A	677A, 678A, 682A	675A, 680A–682A		Sty. 678A–681A	676A–678A	678A, 680A–682A	671A, 672A	
1100–1114½	683A–709A	699A–701A, 703A, 704A	687A, 691A–697A, 699A–707A Lo. 692A, 695A–697A, 704A		Sty. 708A	706A, 708A	683A–690A, 693A, 697A, 698A	683A ?–694A	Go. 692A

in the Cores of the Main Boring, Funafuti—*continued.*

Orbicella.	Hydnophora = Hy. Cyphastræa = Cy. Galaxea = Gx.	Astræan coral, genus uncertain.	Fungia = Fu. Cycloseris = Cs. Psammocora = Psa.	Siderastræa.	Madrepora.	Montipora = Mt. Turbinaria = Tur.	Astræopora.	Porites.	Corals not determined. Aporosa = Ap. Perforata = Per.
	Gx. 425A–427A	438A, 441A	Fu. 442A ?		422A–424A, 426A, 430A–441A	Mt. 422A, 423A, 426A	424A, 425A	422A, 423A, 425A, 426A, 428A, 429A, 434A, 435A. 437A–441A	
449A			Fu. 445A ?		443A, 445A, 449A	Mt. 443A, 445A ?		443A–449A	
		458A, 467A, 468A	Fu. 462A Psa. 470A		453A, 458A, 462A, 465A–468A, 470A	Mt 450A–452A		450A–461A, 465A–470A	
485A, 486A			Fu. 474A		471A–475A, 481A–484A	Mt. 487A, 488A	472A, 473A, 487A–490A	471A–474A, 480A–489A	
		497A			491A, 495A–501A, 505A–507A				502A–504A
	Cy. 523A ?–525A ?	510A, 526A, 527A	Fu. 511A–514A, 523A		508A–514A, 518A, 523A–525A	Mt. 515A	519A ?–521A ?	519A ?–521A ?, 523A ?	511A, 526A Per. 523A
537A–542A	Cy. 533A	536A–538A, 541A, 542A			533A, 535A, 542A	Mt. 535A	536A	536A–542A	
551A–553A		556A, 557A–559A, 562A, 564A	Fu. 557A–559A	554A, 555A	547A–553A, 557A–559A, 560A	Mt. 556A, 557A–559A, 560A–564A	547A 551A	543A–559A	
568A, 571A–578A, $583A_1$		566A–570A			565A–575A, 577A–578A	Mt. 565A	569A, 570A, 573A–575A	565A ?–570A	
584A, 587A, 588A, 590A, 592A		593A, 594A			584A, 591A			$583A_2$–585A, 594A	Per. 592A
595A, 596A, 607A					595A–600A			595A, 596A, 601A, 604A, 605A	Per. 606A
609A–610A, 623A, 624A		611A, 622A, 623A, 627A	Psa. 622A, 623A		608A	Mt. 611A–617A, 620A, 622A		608A–610A	Per. 623A, 627A
628A		628A, 634A			628A ?, 637A, 638A ?				Per. 630A–634A, 642A, 643A
652A, 653A		650A	Cs. 644A ? Fu. 646A		644A				Per. 644A 646A, 649A 655A–659A
666A, 667A, 677A		676A, 678A	Fu. 671A, 672A		665A, 676A, 677A–679A			671A ?, 672A 678A–682A	Per. 668A, 675A, 676A 678A
683A, 684A, 689A	Cy. 695A, 698A	705A, 708A		699A–702A	684A, 689A, 690A, 698A, 706A, 708A	Tur. 693A, 694A		683A, 689A, 690A, 693A ?, 706A	Per. 685A, 689A, 693A, 696A, 707A, 709A

TABLE showing the Distribution of Coral Genera

Depth from surface in feet.	Numbers of cores.	Millepora. Stylaster = Sta.	Alcyonarian spicules. Lobophytum = Lo.	Heliopora cærulea.	Stylophora = Sty. Seriatopora = Ser.	Pocillopora.	Cœloria.	Astræa.	Goniastræa = Go. Prionastræa = Pr.
0– 30	C. 1–C. 5_1			C. 1–C. 5					
30– 50	C. 6–C. 15			C. 7, C. 10, C. 12–C. 15					
50– 80	C. 16–C. 22			C. 16–C. 22	Sty. C. 16			C. 17? C. 19?	
80– 85	C. 23–C. 28	C. 25				C. 24		C. 28	
85–105	C. 29–C. 36		×	C. 29, C. 30	Sty. C. 29				

TABLE showing the Distribution of Coral Genera

0-12									
12-20	D. 1–D. 4								
20-30	D. 5–D. 10								
30-40	D. 11–D. 17	D. 15–D. 17							
40-50	D. 18–D. 35			D. 28					
50-60	D. 36–D. 57	D. 40, D. 41							
60-72	D. 58–D. 74					D. 60, D 68,			

TABLE showing the Distribution of Coral Genera in the

Depth from floor of lagoon in feet.	Number of samples.	Millepora. Stylaster = Sta.	Alcyonarian spicules. Lobophytum = Lo.	Heliopora cærulea.	Stylophora = Sty. Seriatopora = Ser.	Pocillopora.	Cœloria.	Astræa.	Goniastræa = Go. Prionastræa = Pr.
$21\frac{1}{3}$	L. 2								
$35\frac{1}{3}$	L. 3				Ser. ×				
50	L. 4				Ser. ×				
62	L. 5		×	×	Ser. ×				
75	L. 6								
$81\frac{1}{3}$ - 82	L. 7, L. 16		×	×	Ser. ×	×			
$94\frac{1}{4}$	L. 8			×	Ser. ×	×			
$103\frac{1}{3}$–105	L. 9, L. 15				Ser. ×		×		
$106\frac{3}{4}$	L. 11, L. 12				Ser. ×				
$112\frac{1}{3}$	L. 10.				Ser. ×				
116 –144	L. 13–L. 14B		Lo. ×	×		×			

in the Cores of the First Boring (C), Funafuti.

Orbicella.	Hydnophora = Hy. Cyphastræa = Cy. Galaxea = Gx.	Astræan coral, genus uncertain.	Fungia = Fu. Cycloseris = Cs. Psammocora = Psa.	Siderastræa.	Madrepora.	Montipora = Mt. Turbinaria = Tur.	Astræopora. Goniopora = Gnp.	Porites.	Corals not determined. Aporosa = Ap. Perforata = Per.
C. 1. C. 10.			Psa. C. 12, C. 13 Fu. C. 22			Mt. C. 15			C. 6, C. 9, C. 11. Per. C. 22. Per. C.26, C. 27.
C. 28		C. 23				Mt. C. 23, C. 28			
C. 31, C. 32, C. 34, C. 35, C. 36					C. 29	Mt. C. 29, C. 31, C. 32, C. 35.			

in the Cores of the Second Boring (D), Funafuti.

Orbicella.	Hydnophora = Hy. Cyphastræa = Cy. Galaxea = Gx.	Astræan coral, genus uncertain.	Fungia = Fu. Cycloseris = Cs. Psammocora = Psa.	Siderastræa.	Madrepora.	Montipora = Mt. Turbinaria = Tur.	Astræopora. Goniopora = Gnp.	Porites.	Corals not determined. Aporosa = Ap. Perforata = Per.
D. 2?					D. 1–D. 4	Mt. D. 2, D. 3			
D. 7, D. 8					D. 5–D. 8, D 10 D. 11–D. 17	Mt. D. 8.			D. 9
D. 18?					D. 20–D. 26, D. 28–D. 33, D. 35.	Mt. D. 32, D. 35.		D. 19, D. 26 D. 27	D. 34
					D. 36, D. 37, D. 39–D. 50, D. 53–D. 55	Mt. D. 51, D. 52, D. 56, D. 57		D. 36, D. 38, D. 39	
D. 60? D. 74?					D. 58, D. 59, D. 61–D. 64, D. 66–D. 74	Mt. D. 58, D. 59, D. 65, D. 70			

Boring below the Floor of the Lagoon (L), Funafuti.

Orbicella.	Hydnophora = Hy. Cyphastræa = Cy. Galaxea = Gx.	Astræan coral, genus uncertain.	Fungia = Fu. Cycloseris = Cs. Psammocora = Psa.	Siderastræa.	Madrepora.	Montipora. = Mt. Turbinaria = Tur.	Astræopora. Goniopora = Gnp.	Porites.	Corals not determined. Aporosa = Ap. Perforata = Per.
					×			×	
	Cy. ×		Fu. ×						
					×			×	
		×			×		×		
		×			×	Mt. ×			
					×	Mt. ×	Gnp. ×		
		×	Fu. ×		×	Mt. ×	Gnp. ×		
							×		

TABLE of the Distribution of Various Organisms, and of the

Depth from surface in feet.	Nos. of cores.	Calcisponge spicules = Cal. Cliona borings.	Cidaris = Cid. Echinid spines and plates. Holothurian plates = Hol.	Serpula. Spirorbis = Sp.	Ostracoda. (Bairdia = Bd.) Fragments of Crabs = Cra	Polyzoa.	Brachiopoda, Thecidea.
0– 10	1– 11	4	1, 5, 7, 8	3, 7, 8			
			Hol. 5	Sp. 4, 7, 8–11			
10– 20	12– 18		15, 17, 18	12, 15, 17, 18			
20– 30	19– 33	Cal. 21, 22	20–26, 33	21, 22			
30– 40	34– 55	37	34, 36–48, 55	35, 37, 38, 54			
			Cid. 55				
40– 50	56– 59		56	56			
			Cid. 56	Sp. 56, 58, 59			
50– 60	60– 67			Sp. 61, 55		65	
60– 70	68– 84	70–73, 82.	74, 84	68, 69	Bd. 74	69, 74	74
		Cal. 74	Cid. 74	Sp. 70–73, 82	Cra. 74		
70– 80	85– 93	Cal. 90	90		Cra. 90		
80– 90	94–100	95		97, 98			
90–100	101–108		102, 108				
100–110	109–115		109	Sp. 110			
110–120	116–120	119		119		118	
120–130	121–129		121, 123, 125, 128, 129	121, 128			
130–140	130–134		134			134	
140–150	135–137						
150–160	138–141						
160–170	142–143		143	142	143	142, 143	
170–180	144–150		144, 147				
180–190	151–158		157, 158				
190–200	159–175		159, 166, 167–169				
200–210	176–178						
210–220	179–185		179, 180, 183	180, 183	Cra. 180		
220–230	186		186				
230–240	187–188		187				
240–280	189–198		189–191, 193–197			189	
						193–197	
280–290	No solid cores		×				
290–300	,,		×				
300–310	,,					×	
310–320	,,		×		Bd. ×		
320–330	,,						
330–340	,,		×			×	
340–350	,,		×				
350–360	,,		×				
360–370	,,				Bd. ×		
					Cra. ×		
370–373	,,					×	
373–378	199–206	205	204				
378–410	No solid cores		×			×	
410–420	207–213						
420–433	214–222		214				
433–450	No solid cores		×				
450–457	223–229	224, 225, 227, 228	226, 229			223	
457–468	230–233						
468–480	234–236	234	236				
480–497	237–241		239–241				
497–505	242–252		243, 245–252				
505–517	253–258		258	258		255	
517–526	259–267	261, 266, 267	263				
526–546	268–289		269	272			
546–555	290–296		294				
555–567	No solid cores						
567–578	296*a*–296*b*		296*a*, 296*b*				
578–598	297–304					304	
598–612	305–306		305, 306				
612–624	No solid cores						
624–637	307–312	307, 308	307, 308, 309, 311, 312				

Calcareous Algæ in the Cores of the Main Boring, Funafuti.

Lamellibranchs. Lithodomus = Lit.	Gastropoda.	Ascidians. Leptoclinum stellate spicules.	Bones of fish.	Coprolitic pellets.	Corallina.	Halimeda.	Lithothamnion.
	2, 7, 8, 9-11	1, 4, 5					1-11
	17, 18			17, 18			12-18
		21, 22, 24,		23, 32		27-31	19-24, 26-33
		26-32					
		39-47				38	34-51, 53-54
		62, 64					62
69	74, 84	68, 74		74, 84	74, 81	74	68, 70-81, 83
	90	85-87, 89,		90			85-87, 89, 91, 92
		91, 92					
						100	95, 97, 98, 100
		105				102-104	
		110, 114					110, 114
Lit. 117	118					118	
	124, 128, 129						121, 122, 128
	132	132		134			132
		141				141	
						143	
						144, 145	144, 145
						167-169	
						178	
							180, 182, 185
							186
		197				192	
							×
							×
×						×	
						×	
						×	
	200-202, 206	204, 205					199-202, 204, 206
	×						×
							207, 212
	214					215, 216	215, 217, 219
	226-228					229	227-229
	232						
							236
	240					240	239-241
							243, 245-252
							253, 254, 258
263	267					263	259-261, 263, 264,
							266, 267
	272, 276, 281, 283						269-274, 277-280,
							284-289
	295						290-294, 296
						296*a*	
	302						
						305	
	311, 312						

TABLE of the Distribution of Various Organisms, and of the

Depth from surface in feet.	Nos. of cores.	Calcisponge spicules = Cal. Cliona borings.	Cidaris = Cid. Echinid spines and plates. Holothurian plates = Hol.	Serpula. Spirorbis = Sp.	Ostracoda. (Bairdia = Bd.) Fragments of Crabs = Cra.	Polyzoa.	Brachiopoda. Thecidea.
637–643	313–320	313, 316	314–316, 318–320	320			
643–652	321–335	326, 329	321, 322, 324–335				
652–660	336–343		336, 338, 340, 342			340	
660–670	344–347		346				
670–691	348–356		349, 351, 352, 354	354		349	
691–698	357–366		357, 361				
698–706	1A– 2A		1A, 2A				
706–716	3A– 8A		8A	4A			
716–736	9A– 16A		14A, 15A				
736–748	17A– 31A		25A				
748–763	32A– 54A	39A, 45A	47A, 49A, 51A, 54A	37A, 42A, 44A–46A, 49A		32A, 52A, 54A	
763–771	55A– 73A	64A	59A, 63A			56A	
771–781	74A– 96A	88A	75A, 76A	83A, 92A			
781–790	97A–122A		112A, 115A, 120A	97A, 98A, 101A			
790–798	123A–144A	133A, 136A	124A, 131A, 133A, 136A, 137A	126A–128A, 131A, 132A			
798–804	145A–156A	145A, 146A, 148A					
804–810	157A–174A		161A, 165A, 168A, 174A	165A			
810–815	175A–186A	178A	183A, 184A				
815–822	187A–197A		187A, 189A, 190A, 192A–197A	188A			
822–833	198A–215A		199A–204A, 206A–208A, 213A				
833–844	216A–234A		216A–230A				
844–853	235A–248A		240A, 242A–248A				
853–866	249A–276A		249A–276A				
866–874	277A–296A		279A–282A, 292A	284A–286A			
874–881	297A–310A	303A	297A–299A, 307A, 309A, 310A				
881–890	311A–325A	311A, 316A, 317A	320A, 321A	311A, 313A			
890–899	326A–340A	326A	328A, 336A, 337A			326A	
899–910	341A–353A	348A–350A	352A	345A			
910–922	354A–376A	366A, 367A, 372A, 374A–376A	363A, 364A, 368A, 371A–376A	354A–357A, 363A, 364A			
922–936	377A–404A	397A, 402A, 403A	398A, 399A–403A	377A, 379A			
936–945	405A–421A	407A	405A–407A	408A			
945–957	422A–442A	436A	424A, 428A, 429A, 431A–433A, 436A–438A	425A			
957–963	443A–449A		443A, 445A–448A	443A			
963–973	450A–470A	458A–461A	456A–461A, 465A, 467A, 470A	453A, 458A–461A			
973–983	471A–490A	474A, 475A	471A, 476A–479A, 481A–488A				
983–991	491A–507A		491A–507A				
991–1006	508A–527A		508A–521A				

Calcareous Algæ in the Cores of the Main Boring, Funafuti—*continued*.

Lamellibranchs. Lithodomus = Lit.	Gastropoda	Ascidians. Leptoclinum stellate spicules.	Bones of fish.	Coprolitic pellets.	Corallina.	Halimeda.	Lithothamnion.
	316					316–320	320
	335					325, 328, 331, 333–335	325, 327, 332
340	336					336, 338, 340–343	338
						345	345
						348, 349	348, 350, 352, 354, 355
						357–359, 361–366	361–364
2A						1A, 2A	
						4A–8A	
	11A					12A–16A	10A, 12A
26A–27A	22A					17A–25A	21A–24A, 31A
39A, 47A	42A					36A, 40A, 46A	41A, 42A, 45A–49A
65A, 67A, 68A	61A					59A, 71A	70A
84A, 91A	96A					86A, 89A, 90A, 92A, 96A	85A, 86A, 89A, 92A, 94A, 95A
97A, 98A	99A, 100A, 112A	104A				101A, 105A–107A, 112A–115A, 120A	101A, 104A, 105A, 108A–120A
	124A, 133A–135A					123A, 133A, 135A, 139A, 140A	131A–142A
145A, 146A						149A	145A, 146A, 149A–154A
160A	160A, 161A, 165A, 174A	163A				157A, 161A	158A–171A
		183A				178A, 183A, 184A	175A, 178A, 181A
188A	187A, 189A						
190A, 211A, 212A	199A, 202A, 211A 212A					213A	205A, 208A
232A	220A–222A, 224A					224A ?	217A, 224A–227A, 229A, 231A–234A
241A	241A					235A, 242A–248A	235A, 238A–240A
		258A					261A, 268A, 272A–276A
	296A					284A–286A, 294A, 295A	287A, 292A–295A
	297A, 301A, 307A, 308A, 310A						297A, 300A, 303A, 304A, 306A, 307A, 309A
319A	311A, 312A, 314A, 315A, 318A, 321A						311A–313A, 316A–325A
	327A–335A	329A					326A–340A
346A, 347A, 350A	345A	352A					341A–353A
357A	354A, 359A, 362A, 366A–370A						354A–357A, 359A–376A
398A, 399A	394A, 396A, 404A	398A, 399A				388A, 389A	380A–397A, 400A–404A
	410A, 411A, 413A, 414A, 418A 420A						405A–407A, 410A–412A, 418A–420A
424A, 437A	424A, 425A, 431A–433A, 437A, 439A						422A–442A
446A–448A	443A, 445A–448A						443A–448A
450A–452A, 458A–464A	462A, 468A, 470A						450A–461A, 467A–470A
472A–475A	480A	488A					471A–488A
	497A						491A–507A
511A, 512A	523A						508A–527A

TABLE of the Distribution of Various Organisms, and of the

Depth from surface in feet.	Nos. of cores.	Calcisponge spicules = Cal. Cliona borings.	Cidaris = Cid. Echinid spines and plates. Holothurian plates = Hol.	Serpula. Spirorbis = Sp.	Ostracoda. (Bairdia = Bd.) Fragments of Crabs = Cra.	Polyzoa.	Brachiopoda. Thecidea.
1006–1015	528A–542A	535A	528A–534A, 537A, 542A	534A, 541A, 542A			
1015–1025	543A–564A		543A–553A, 557A–559A				
1025–1034	565A–$583A_1$	568A, 573A–575A	566A, 571A–578A, $583A_1$				
1034–1044½	$583A_2$–594A	589A, 593A, 594A	$583A_2$–585A, 589A–594A				
1044½–1053	595A–607A	595A, 604A, 605A	595A–607A	595A, 601A			
1053–1066	608A–627A	624A, 625A	608A–620A	621A, 625A			
1066–1075	628A–643A		628A, 637A–643A				
1075–1087	644A–661A	644A, 650A–652A	646A–649A, 655A, 659A				
1087–1100	662A–682A	680A–682A	662A–678A, 680A, 681A				
1100–1114½	683A–709A	683A, 696A, 699A, 703A–706A, 708A Cal. 703A	683A, 688A–692A, 695A–698A	690A, 702A			

Calcareous Algæ in the Cores of the Main Boring, Funafuti—*continued.*

Lamellibranchs. Lithodomus = Lit.	Gastropoda.	**Ascidians. Leptoclinum: Stellate spicules.**	**Bones of fish.**	**Coprolitic pellets.**	**Corallina.**	Halimeda.	Lithothamnion.
540A, 542A	**536A**					537A, 542A	**528A–542A**
544A, 555A, 557A–561A	544A, 554A, 555A, 557A–564A	562A				**553A**	**543A–564A**
565A, 566A, 569A	565A, 566A, 570A, 571A, 576A					576A, 583A$_1$	**565A, 569A–583A$_1$**
583A$_2$–588A	584A, 585A, 590A					592A–594A	**583A$_2$–594A**
595A, 598A–600A	595A, 598A–600A, 604A–606A					595A, 597A, 603A	**595A–607A**
622A, 623A	608A–617A, 622A–626A		621A				608A–620A, 623A–625A
635A							628A, 630A–643A
659A	**646A**					646A	644A, 646A, 649A–659A
668A–670A, 673A, 680A	676A, 678A	677A, 682A				675A, 677A, 678A ?	662A–668A, 675A, 678A–682A
688A, 689A, 693A, 701A–704A, 708A	683A, 686A, 688A, 692A, 696A, 699A, 703A–708A	699A					683A–688A, 691A, 695A–698A, 701A, 703A–705A, 707A–709A

TABLE of the Distribution of Various Organisms and of the

Depth from surface in feet.	Nos. of cores.	Calcisponge spicules = Cal. Cliona borings.	Cidaris = Cid. Echinid spines and plates.	Serpula. Spirorbis = Sp.	Ostracoda. (Bairdia.) Claws of crabs = Cr.	Polyzoa.
0 – 30	C. 1–C. 5_1		C. 1, C. 2, C. 4, C. 5_1	C. 1–C. 4, C. 5_1		C. 1
30– 50	C. 6–C. 15	Cal. C. 7, C. 9, C. 12, 15 C. 7	C. 6, C. 8, C. 10–C. 12			
50– 80	C. 16–C. 22	C. 18	Cid. C. 16 C. 16, C. 19, C. 20	C. 16, C. 20 Sp. C. 17		
80– 85	C. 23–C. 28	C. 24, C. 27	C. 27	C. 23, C. 26, C. 27, C. 28 Sp. C. 23, C. 24. C. 25, C. 28		
85–105	C. 29–C. 36	C. 31	×	C. 29, × Sp. C. 33, C. 36, ×		C. 29 C. 36

TABLE of the Distribution of Various Organisms and of the

0 –12						
12–20	D. 1–D. 4	D. 4	D. 2–D. 4	D. 2, D. 3		D. 2
20–30	D. 5–D. 10	D. 5, D. 6				
30–40	D. 11–D. 17	D. 11, D. 16 Cal. ×	D. 17	D. 15, D. 17 Sp. D. 16, D. 17		
40–50	D. 18–D. 35	D. 19, D. 21–D. 23, D. 28	D. 23 ×	D. 18–D. 21 Sp. D. 25, D. 28, D. 29, D. 32, D. 34, D. 35	Cr. × ×	
50–60	D. 36–D. 57	D. 45, D. 46–D. 50, D. 53, D. 54, D. 56	D. 57	Sp. D. 36, D. 37, D. 39, D. 45		
60–70	D. 58–D. 74	D. 58, D. 59, D. 65–D. 67, D. 71, D. 72 Cal. ×	D. 60, D. 65, D. 67 ×	D. 59, D. 70 Sp. D. 59, D. 60, D. 66, D. 67, D. 68, D. 70	×	

TABLE of the Distribution of Various Organisms and of the Calcareous

Depth from floor of lagoon in feet.	Nos. of samples.	Calcisponge spicules = Cal. Cliona borings.	Cidaris = Cid. Echinid spines and plates.	Serpula. Spirorbis = Sp.	Ostracoda. (Bairdia.) Claws of Crustacea = Cra.	Polyzoa.
21½	L. 2		×	× Sp. ×	×	×
35½	L. 3		×	×		×
50	L. 4	Cal. ×	×	×	×	×
62	L. 5	Cal. ×	×	×	× Cr. ×	×
75	L. 6		×			×
81½, 82	L. 7, L. 16	×	×	× Sp. ×		
94¾	L. 8		×			×
103½–105	L. 9, L. 15			×		
106¾	L. 11, L. 12		×			
112½	L. 10		×	×		
116 –144	L. 13–L. 14B	×	×	× Sp. ×		×

Calcareous Algæ in the Cores of the First Boring (C), Funafuti.

Brachiopoda. Thecidea.	Lamellibranchs.	Gastropoda.	Ascidians. Leptoclinum. Stellate spicules.	Coprolitic pellets.	Corallina.	Halimeda.	Lithothamnion.
		C. 1–C. 4, C. 5_1	C. 4, C. 5_1	C. 4		C. 1, C. 2	C. 1–C. 5_1
		C. 10	C. 6, C. 7, C. 9, C. 10, C. 12			C. 11–C. 13	C. 6, C. 7, C. 9–C. 12, C. 13, C. 15
		C. 16, C. 19, C. 20	C. 19, C. 22			C. 16, C. 19, C. 20, C. 22	C. 16, C. 18–C. 22
			C. 24				C. 24, C. 26
	C. 28		C. 29, C. 36 ×	×		×	C. 29, C. 31, C. 34–C. 36 ×

Calcareous Algæ in the Cores of the Second Boring (D), Funafuti.

Brachiopoda. Thecidea.	Lamellibranchs.	Gastropoda.	Ascidians. Leptoclinum. Stellate spicules.	Coprolitic pellets.	Corallina.	Halimeda.	Lithothamnion.
		D. 17	D. 2, D. 5, D. 6, D. 9, D. 15				D. 1–D. 4, D. 9, D. 15, D. 17
			D. 22, 25, D. 28_1	×	×		D. 18, D. 21, D. 22, D. 28–D. 29, D. 31, D. 32, D. 34, D. 35, D. 36, D. 45, D. 51, D. 56, D. 57
			D. 39				
	×	D. 72	D. 61, D. 65, D. 67, D. 72				D. 58, D. 59, D. 62–D. 67, D. 69, D. 70, D. 72, D. 74

Algæ in the Boring below the Floor of the Lagoon (L), Funafuti.

Brachiopoda. Thecidea.	Lamellibranchs.	Gastropoda.	Ascidians. Leptoclinum. Stellate spicules.	Coprolitic pellets.	Corallina.	Halimeda.	Lithothamnion.
	×	×				×	
		×	×			×	
×	×	×		×		×	
×	×	×				×	
	×	×	×			×	
×	×	×				×	
		×	×			×	
	×					×	
						×	
		×				×	
×	×	×	×			×	×

SECTION XII.

THE CHEMICAL EXAMINATION OF THE MATERIALS FROM FUNAFUTI.

By Professor J. W. JUDD, *C.B., LL.D., F.R.S.*

CONTENTS.

1. METHOD OF ANALYSIS.

ON the arrival in 1897 of the first portions of the core from the Main Boring at Funafuti, which had then been carried down to the depth of 698 feet, I found in the lower portions of the materials brought up unmistakable evidence of an extensive replacement of calcium carbonate by magnesium carbonate. The interest attaching to the chemical changes which undoubtedly go on in coral-reef rocks, as was long ago shown by DANA—an interest which had been revived by the results obtained by Sir JOHN MURRAY at Christmas Island—suggested the great importance of a thorough chemical examination of the whole of the specimens which were being obtained at Funafuti.

A series of samples, thirty in number, taken at short intervals from this portion of the bore-hole, were, therefore, entrusted to Dr. C. G. CULLIS for analysis by ordinary gravimetric methods.

The phosphoric acid was precipitated as ammonium phospho-molybdate, the

calcium as oxalate, and the magnesium as pyrophosphate. In the earlier analyses, the calcium oxalate was converted by ignition into oxide, and weighed in that state, but in the later part of the work it was found more convenient to convert it into sulphate before weighing.

On the arrival in the following year of the remaining 416 feet of core, this work of chemical examination was continued by the analysis of twenty more samples, taken at intervals, ten of these being executed by Dr. C. G. CULLIS and ten by Dr. E. W. SKEATS. In making these analyses, my assistants were greatly aided by the advice given to them by Dr. W. A. TILDEN and the members of the Chemical Staff of the Royal College of Science.

As the interesting and sometimes rapid changes in the proportions of calcium and magnesium in the cores came to be recognised by means of these analyses, the desirability of a more expeditious method of determining the relative amounts in which the two bases were present became apparent. After consultation with Dr. TILDEN and the members of the Chemical Board of the Government Grant Committee of the Royal Society, it was determined to adopt the volumetric method for the estimation of the calcium, by titration with potassium permanganate. The amount of phosphates and other materials in all parts of the core had already been shown to be exceedingly minute, and consequently the magnesium could be safely estimated by difference. Funds for the purpose having been supplied by the Government Grant Committee of the Royal Society, the work was entrusted to Mr. J. HART-SMITH, and was carried on in the laboratories of the Chemical Division of the Royal College of Science under the supervision of Dr. TILDEN. The accuracy of these volumetric analyses was tested from time to time by the ordinary gravimetric methods.

Sixty-three volumetric analyses of the materials from the Main Boring, with nineteen analyses of samples from the two earlier borings of Professor SOLLAS (some of these analyses being in duplicate), were made by Mr. J. HART-SMITH.

At a later date, Dr. E. W. SKEATS made in the Geological Research Laboratory twenty more volumetric analyses, by the same method, of samples taken from the Main Boring, and of fifty-three of samples taken from Professor SOLLAS' borings. It will thus be seen that the conclusions in the following pages are based on 133 analyses of samples from the Main Boring—fifty of these analyses being gravimetric and eighty-three volumetric—and seventy-two analyses of samples from Professor SOLLAS' two borings, nearly all of which were volumetric.

2. GENERAL RESULTS OF ANALYSES OF THE CORES.

The general results arrived at by these analyses, so far as they relate to the Main Boring, are represented graphically in fig. 23, A, B, C, D, from which it will be seen that samples were taken generally at intervals of 10 feet, but where rapid changes were

 Main Boring. Diagram showing Proportion of Calcium and Magnesium Carbonate at different Depths.

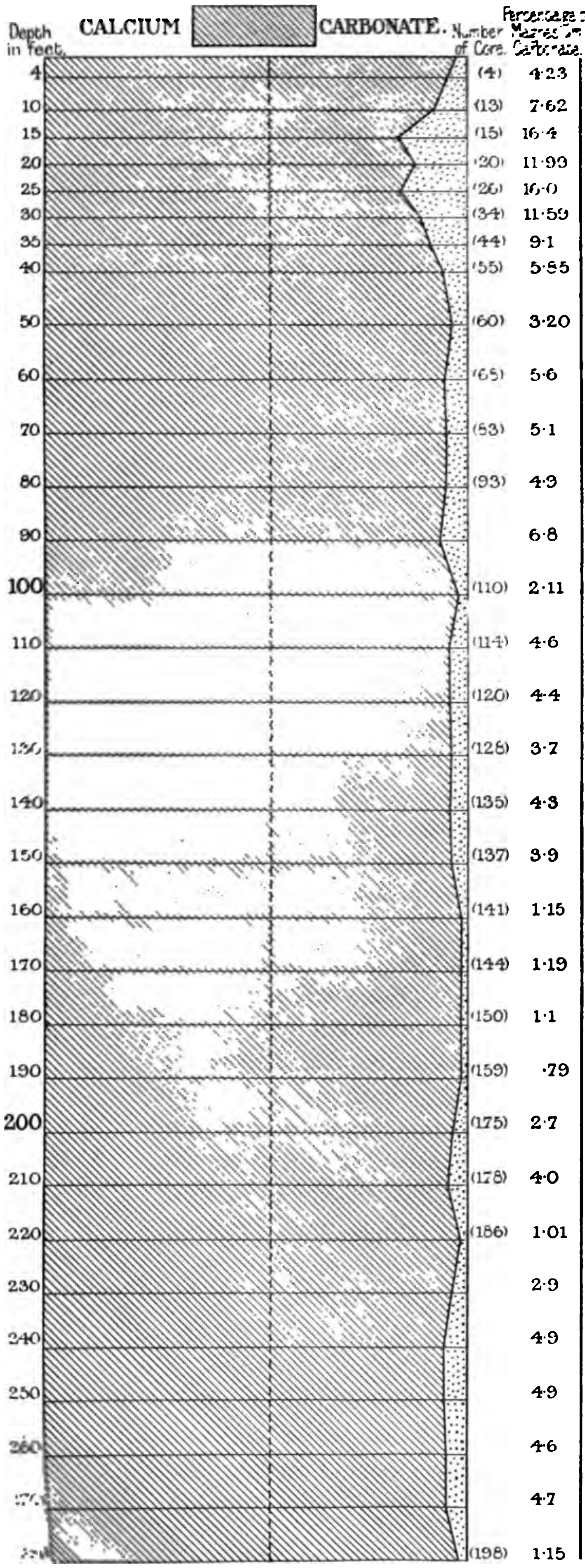


Fig. 23, A.

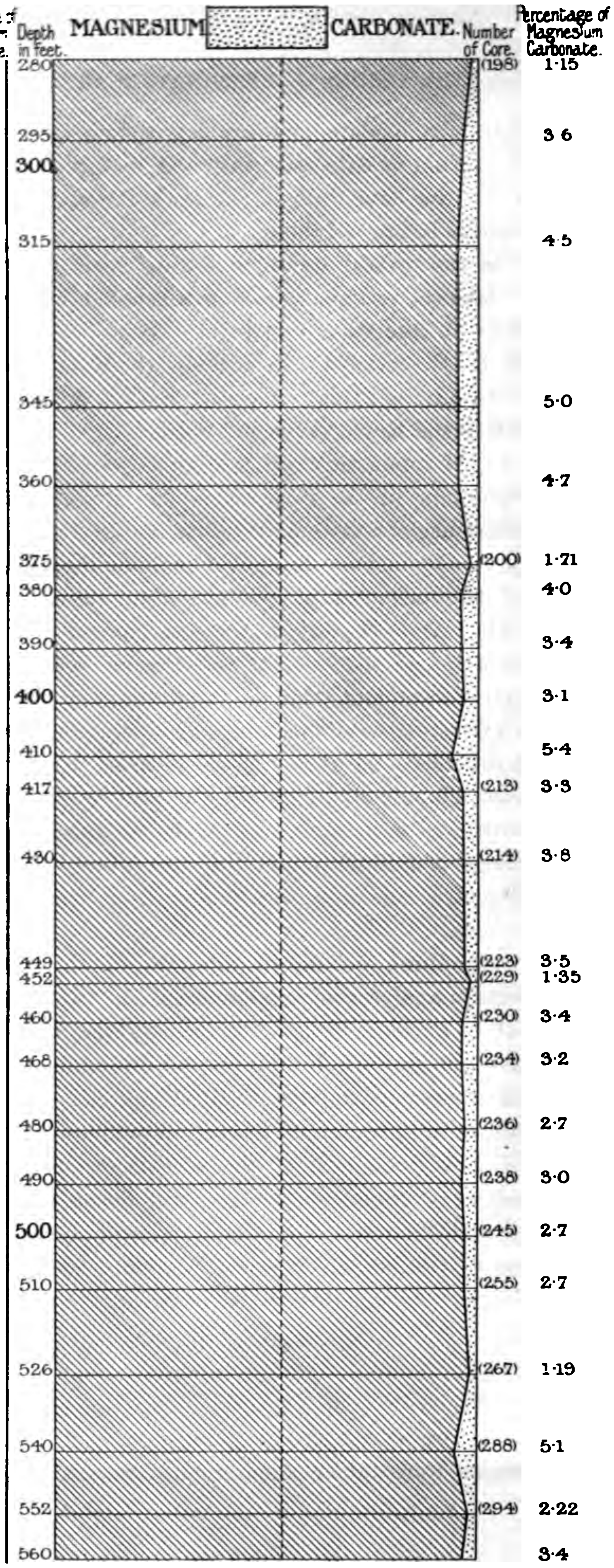


Fig. 23, B.

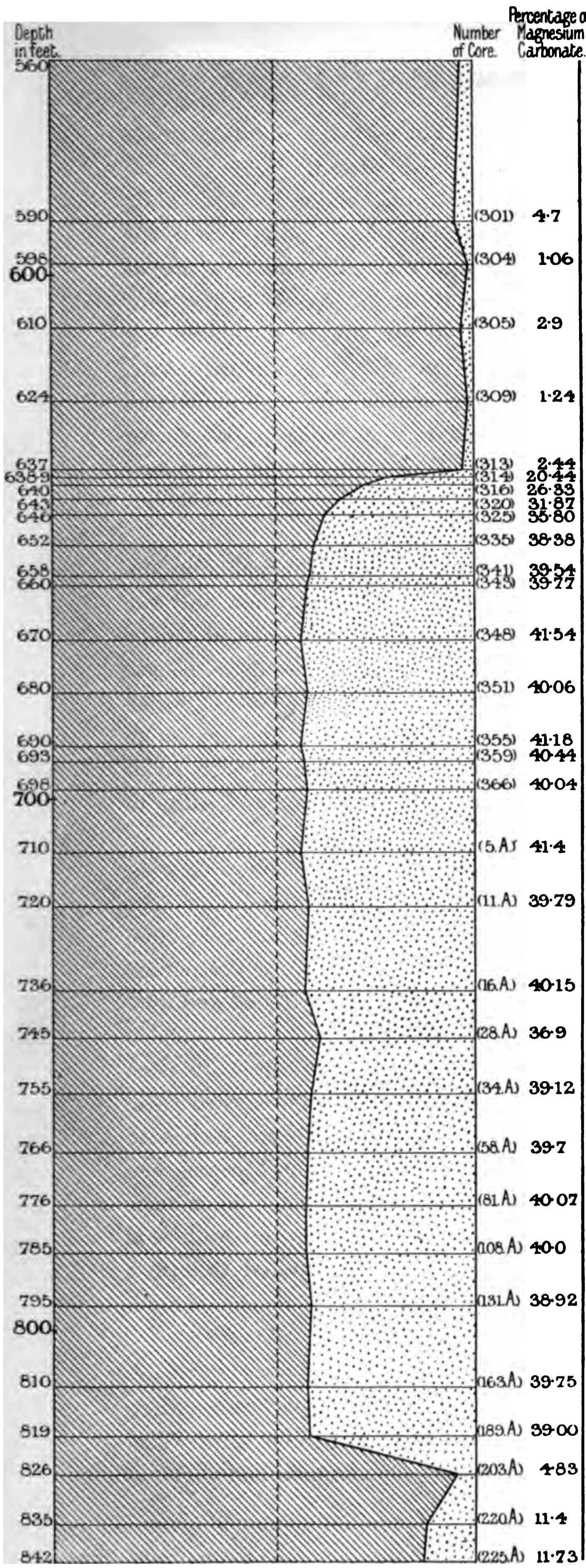


Fig. 23, C.

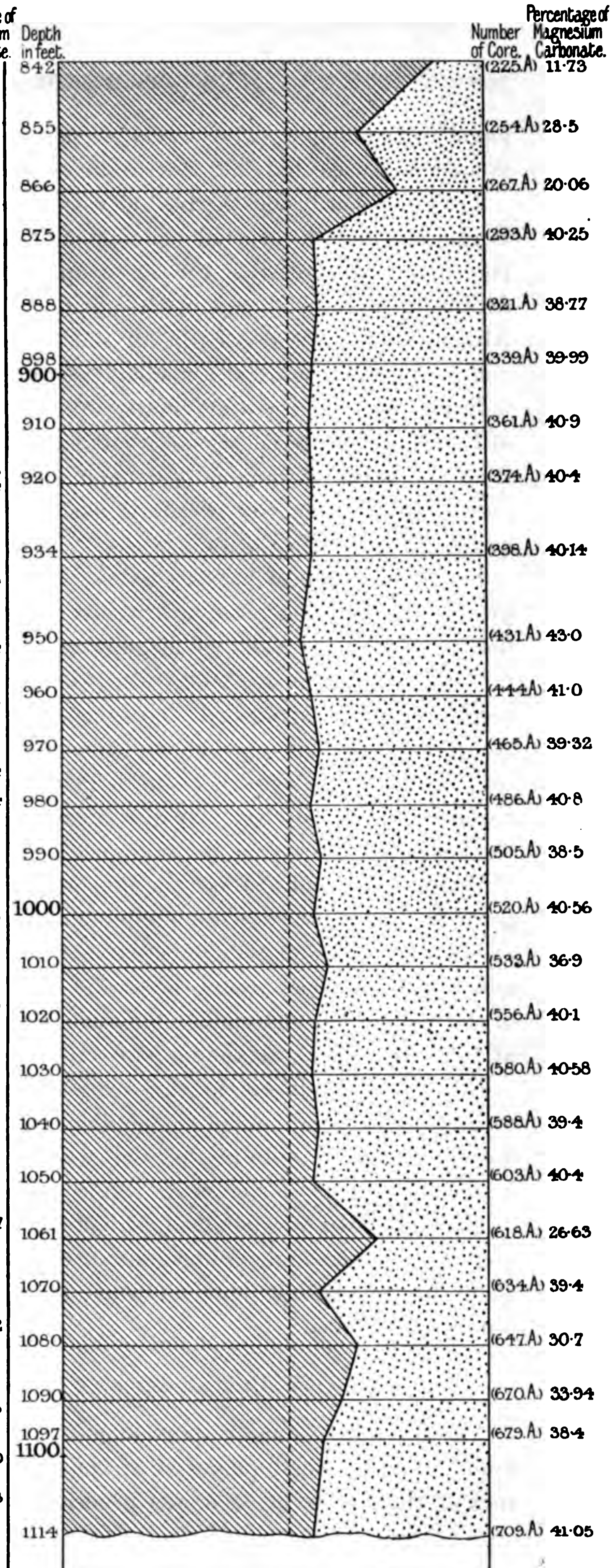


Fig. 23, D.

found to be going on in the relative proportions of the two carbonates, intermediate samples were selected, and the results of their analyses interpolated.

The chief conclusions arrived at from the analysis of samples taken from the Main Boring are as follows :—In the first 50 feet of descent there is a gradual rise in the percentage of magnesium carbonate up to 16 per cent., this maximum occurring at depths of 15 and 25 feet, with a falling off between those depths to 12 per cent. Although the exact depths of all the samples from Professor SOLLAS' two borings is not given, yet there is a similar rise in the proportion of magnesium carbonate, indicated between the same limits of depths in both of these borings. As the second of Professor SOLLAS' borings is situated at a distance of more than a mile-and-a-quarter from the Main Boring, it is evident that this rise of the magnesium carbonate percentage in going downwards is not a mere local phenomenon, but occurs over a considerable area in the atoll.

From the depth of 25 feet in the Main Boring there is a gradual decline in the proportion of the magnesium carbonate present, till 50 feet is reached, when only the normal 1 to 5 per cent. of magnesium carbonate is present. This state of things prevails to the depth of 637 feet, when a rapid rise in the magnesium carbonate percentage again commences, and is continued till a depth of 658 feet is reached, when the proportion of magnesium to calcium carbonate has attained the limit of 40 to 60. This high percentage of 40 of magnesium carbonate is maintained with small variations, and two important interruptions, to be more closely particularised, quite to the bottom of the boring at 1114½ feet.

Between 819 and 875 feet the proportion of magnesium carbonate declines, showing great variations, but reaches a minimum of 4·8 at 826 feet, and a second one of 20·6 at 866 feet, with a maximum between them of 28·5 at 855 feet. Again, between 1050 and 1097 feet there occurs the second but less marked falling off in the percentage of the magnesium carbonate. We have here minima of 26·63 at 1061 feet and 30·7 at 1080 feet, with a maximum between them of 39·4 at 1070 feet.

It is specially noteworthy that while the proportion of magnesium carbonate rises so high as to approximate to the quantity necessary to make the double carbonate, dolomite, it never quite reaches that limit. The proportion of magnesium carbonate in dolomite is 45·65 per cent., while the sample in which the highest percentage of that substance was detected, at 950 feet deep, contained 43 per cent. As a rule, however, the percentage of magnesium carbonate in this lower part of the bore-hole is about 40, thus falling short by nearly 6 per cent. of the quantity required to form a complete dolomite.

3. Preparation of Samples for Analysis.

All the cores brought from Funafuti, having been immersed in sea-water, were found to retain small quantities of chlorides, sulphates, and other soluble salts. The rock of the reef, so far as it was penetrated, was more or less cavernous and pervious

in character; its lower portions would have their cavities permanently filled with sea-water, while, in the upper part of the reef, the sea-water flows to and fro with the rise and fall of the tide. During the boring operations, sea-water was constantly conducted down the bore-hole in order to carry away the fine particles produced by the grinding of the diamond-crown. The cores thus saturated with sea-water would, of course, retain some of the soluble salts on being brought to the surface and dried.

It is evident, however, that no useful purpose would be served by determining the exact amount of these soluble salts which were retained by different specimens. Various accidents, such as the draining away of water from them, the exposure to rain or similar conditions, would deprive the exact proportion in which these soluble salts were present of all significance. It was determined therefore to neglect altogether these soluble constituents, and at the outset all the samples were thoroughly washed with distilled water before being submitted to analysis.

The Funafuti cores, as brought home, all exhibited a more or less pronounced brownish-yellow tint on their exposed surfaces. On being cut open, however, the cores were found to be creamy white in colour, except between the depths of 687 and 748 feet, where the rock exhibited an earthy texture and a chalk-like whiteness, as it also did at a few points below. The yellow pieces of core when placed in dilute acid had the coloured film removed from them at once, and it was evident that this external colour was accidental—due to the deposition of a slight film of iron oxide, derived from the boring tools, rods, and lining tubes. The analyses were therefore performed on samples taken from the interior of the cores, where free from this iron-staining.

In some of the samples brought from Professor SOLLAS' boring, from a small depth below the surface, there were naturally exposed surfaces of the solid cores which showed a much darker brown tint, due to a film deposited upon them. It was found quite impossible to separate this film for analysis, but various tests showed that it contained iron, though manganese could not be detected in it. I think this separation of iron-oxide must have been due to the action of vegetation, which had extracted ferruginous salts from the soil and deposited the oxide on the decay of the plant-tissues. But it is remarkable that where, as we shall see in the sequel, there is so small an amount of mineral matter available, with the exception of calcium carbonate, plants should be able to find the iron compounds and take them up into their tissues.

4. PROPORTION OF ORGANIC MATTER IN THE SAMPLES.

The proportion of organic matter retained in the calcareous skeletons of various organisms is liable to constant variation on the death of the organism, and is very difficult of determination. In the case of corals, we meet with special difficulties, for one part of a mass of coral may be dead and undergoing decay, while other portions of the same mass may be living. This is well shown in some of the specimens sent

home by Mr. FINCKH, to illustrate the method and growth of corals. We have examples of *Astræopora* and other forms, in which a mass of dead and much decayed coral is being enveloped in a fresh layer formed by the calices of living polyps.

BENJAMIN SILLIMAN, JUNR., estimated the proportion of organic matters present in various genera of corals as varying from 2–8 per cent.*

S. P. SHARPLES, analysing a series of specimens dredged by Count POURTALES off Florida and Cuba, found the limits of the proportions of organic matter and water, taken together, to lie between 1 and 4 per cent.†

The analyses made of corals and coral-reef rock by Professor LIVERSIDGE‡ indicate the presence of an even smaller proportion of organic matter in such materials, for he found less than 1 per cent. of water and organic matter, taken together, in a reef-coral from the New Hebrides. Later analyses by different chemists seem to indicate that the quantity of organic matter retained in dead coral is generally very small indeed.

The analyses of the Funafuti cores indicate that in the surface rock the quantity of organic matter is small, seldom, if ever, exceeding 1 per cent.; that at a depth of 50 feet it is so minute as to be safely negligible, while at depths below 100 feet the quantity of organic matter is quite inappreciable.

5. PROPORTION OF INSOLUBLE (INORGANIC) MATTER IN CORAL-REEF ROCKS.

The study of this subject in the case of the materials from Funafuti, has led to some very interesting results, which have an important bearing on certain geological questions.

When, after being prepared in the manner described in the foregoing pages, the samples from Funafuti were dissolved in acid, it was found that the quantity of insoluble residue was, in all cases, almost inappreciable. As every specimen had to be dissolved for analysis, it was obvious that there could be no room for error on this point. In order, however, to remove any possibility of doubt, large quantities of material were from time to time submitted to solution, but always with the same result, a very minute quantity of insoluble matter being left behind.

As a final check to these results I requested Dr. SKEATS to dissolve very considerable quantities of the rock taken at different depths from the bore-hole, and after submitting them to slow solution in very dilute acid, so as to avoid risk of decomposition of basic or hydrous silicates, to weigh the residue (always a very minute one) in each case. These tests were repeated from materials taken at intervals all down the bore-hole, till there could be no doubt as to the result.

* 'Amer. Journ. Sci.,' 2nd series, vol. 1 (1846), p. 189. See also 'Report of the United States Exploring Expedition (Zoophytes),' 1846, p. 712.

† 'Amer. Journ. Sci.,' 3rd series, vol. 1 (1871), p. 168.

‡ 'Journ. Royal Society of New South Wales,' vol. 14 (1881), pp. 159–162.

Some of the numbers thus obtained were as follows :—

Number of core.	Depth in feet.	Weight of rock dissolved.	Percentage of insoluble residue.
6	10	91·50 grammes	·003
192	260	52·07 "	·083
364–5	670–698	70·07 "	·006
72A	763–771	167·18 "	·001
384A	922–936	100·4 "	·013
652A	1075–1087	122·4 "	·004

In the case of the largest of these residues, that from 260 feet, an attempt was made to determine its composition. Only ·04 gramme was available, but on fusion with carbonates and ignition this yielded 12·75 per cent. of silica, the dissolved portion consisting principally of ferric oxide and alumina.

Very similar results have been obtained by Mr. STANLEY GARDINER in examining a series of coral-rocks and "coral-sands" from the Maldive atolls.* In these, analysis showed that the quantity of silica present varied from ·0013 to ·076, omitting the cases in which argillaceous matter might have been present. The average of nine examples from Minikoi gave only ·046 per cent. of silica; a specimen from Hulule gave ·024 per cent. of silica; while the average of four specimens from Suvadiva gave only ·003 per cent. of silica. The bases found to be present by Mr. STANLEY GARDINER were calcium, magnesium, aluminium, and iron.

The series of specimens from Christmas Island and from the raised reefs of the Pacific, for which I am indebted to Sir JOHN MURRAY and Professor A. AGASSIZ respectively, have afforded to Dr. SKEATS the means of determining the amount of insoluble inorganic matter from widely separated coral reefs all over the globe. He found in all cases that "insoluble residue is present in exceedingly small quantities," except where the limestones are associated with volcanic rocks.†

This minute proportion of insoluble residue in the Funafuti rocks appears at first sight somewhat difficult of explanation. Dr. HINDE and Mr. KIRKPATRICK show that traces of siliceous sponges are present both among the organisms collected on the reef and also in the rocks of the reef brought up as cores from the borings. Indeed, as Dr. HINDE has pointed out, the borings of *Cliona* are very frequent. It would appear, therefore, that the colloid silica of sponge spicules and of radiolarians, diatomaceæ, &c., must, under the conditions that are present in the reef, pass again into solution before the silica is converted into the crystalline and insoluble form.

There is another source of insoluble matter which must not be overlooked. In the

* 'The Fauna and Geography of the Maldive and Laccadive Archipelagoes,' vol. 1, Part 3, pp. 322–323.

† 'Bull. Mus. Comp. Zool. Harvard College,' vol. 42 (1903), p. 103.

description of the geology of Funafuti it will be seen that considerable quantities of pumice are found washed up on the beaches. As is pointed out in the account of the Geology of the Island (pp. 76–77), the Hurricane Bank contains a thin but very persistent band of pumice, formed of materials which were floated across the Pacific after the eruption at Blanche Bay in New Britain in 1878. Dr. HINDE informs me that in no instance during his detailed examination of the cores did he detect any trace of pumice in them; a particle which he found in loose material may have fallen in from above. The absence of silicates and other insoluble matter in the cores, as shown by their chemical analysis, proves that fragments of pumice and similar volcanic materials are very rarely enclosed in the coral-rock. In all probability such materials, though they may be stranded on the beaches for a time, are washed away again before becoming embedded in the limestone rock. Like all sub-äerial accumulations, they can only be preserved in submarine deposits by a combination of accidents.

It will be seen from the table given on the preceding page, that the quantities of insoluble inorganic matter in the cores of Funafuti, show no tendency to increase in going downwards. Near the bottom of the core, at a depth of between 1075 and 1087 feet, an insoluble residue of only ·004 per cent. was obtained, this being about the usual average amount found from top to bottom of the boring, except in one or two special cases. It is fair to conclude, therefore, that the boring, at its greatest depth, exhibited no indication of the proximity of volcanic rock or any materials containing silicates. The atoll is so large that in the centre of the lagoon non-calcareous material may exist enveloped and buried in coral-reef rock, and such non-calcareous material may be indicated more or less obscurely by the results of the magnetic survey (see p. 36); but so far as the study of the rocks obtained from the boring affords any means of judgment, there is no more indication of the proximity of any foreign rocks at the depth of 1114 feet than there was at the surface.

The analysis of the deep-sea deposits brought home by the "Challenger" showed that in all cases the calcareous deposits from the ocean floor contain a proportion of insoluble matter, which generally varies between at least 1 and 3 per cent.; Sir JOHN MURRAY assures me that, as the result of his wide experience, it may be accepted as a proved fact that such a proportion of insoluble matter is characteristic of all deep-sea calcareous deposits.

Hence, as coral-reef rocks have now been shown to be distinguished, except when formed in proximity to volcanic masses, *by the almost complete absence of insoluble inorganic matter*, the geologist obtains a criterion by which he may probably be able to distinguish limestones which have been formed on and around coral reefs, from those which have been accumulated on the floor of the open ocean. An analysis of the limestone will show, in every case, whether it consists almost wholly of pure carbonates, indicating that it is of coral-reef origin, or if it contains the normal proportion of silicates found in all the oceanic oozes.

6. Proportion of Phosphates in the Materials from Funafuti.

The early analyses of corals and other marine calcareous organisms made by HATCHETT* and BENJAMIN SILLIMAN, JUNR.,† showed that besides the calcium and magnesium carbonates, various other substances were present in small quantities; in addition to silicon, aluminium and iron, corals have been found to contain both phosphorus and fluorine.

Of the other salts combined with the carbonates of the corals, the phosphates appear to be the most ubiquitous and important. SILLIMAN found minute quantities of phosphoric acid in nearly all the corals which he analysed. SHARPLES in his analyses carried on the laboratory of Professor BRUSH, in the Sheffield Scientific School, Yale University, found much larger amounts of phosphoric acid. He arrived at the conclusion that corals contain from 0·3 to 0·8 of calcium phosphate,‡ while a rock composed of coral fragments dredged by Count POURTALES from the ocean beneath the Gulf Stream between Cuba and Florida, yielded 1·20 of calcium phosphate. As we shall see in the sequel, the amount of phosphoric acid found by SHARPLES in corals and in coral-rock, is much in excess of what other analysts have obtained, and it seems probable that there was some source of error in the chemical methods employed by the analyst, or else that his specimens were of somewhat exceptional character. SHARPLES, indeed, argues as the result of his studies, that the proportion of phosphates may undergo an increase in materials of this kind as they lie on the ocean-floor.

LIVERSIDGE,§ COOKSEY,‖ POLLARD,¶ STEIGER,** HARRISON†† and other chemists have only detected minute traces of phosphates either in corals or coral-rocks; and the preliminary qualitative analysis of the Funafuti rocks showed phosphates to be present only in very minute quantities. In order that the question of the proportion of phosphates in the rocks from the Main Boring at Funafuti should be placed beyond doubt, I requested Dr. CULLIS and Dr. SKEATS to determine the amount of those salts in some of the cores which showed unmistakable evidence of their presence. The determination of the phosphates was made in the same way as in the earlier analyses (see p. 362), by their precipitation as ammonium phospho-molybdate.

The results obtained are given on the following page, the proportions of calcium phosphates at the several depths being stated :—

* 'Phil. Trans.,' vol. 90 (1800), p. 327.

† 'Amer. Journ. Sci.,' 2nd series, vol. 1 (1846), p. 189; 'United States Exploring Expedition' (Zoophytes), 1846, p. 712.

‡ 'Amer. Journ. Sci.,' 3rd series, vol. 1 (1871), p. 168.

§ 'Journ. Proc. Roy. Soc., New South Wales,' vol. 14, pp. 159–162.

‖ Memoir III., Austral. Museum, Sydney. 'The Atoll of Funafuti,' Part 1, p. 76.

¶ 'Proc. Camb. Phil. Soc.,' vol. 9, p. 417.

** 'Bull. Harvard Coll. Mus.,' vol. 26 (1895–6), p. 85.

†† 'Quart. Journ. Geol. Soc.,' vol. 47 (1891), pp. 197–245.

Depth of core in feet.	Percentage of calcium phosphate.
About 15	·136
„ 526	·200
„ 598	·124
„ 660	·150
„ 690	·168
„ 898	·217
„ 1003	·195
„ 1108	·288

By the method of analysis adopted, the presence of phosphates would be at once indicated, and if they had occurred in marked quantity in any sample taken for analysis, the circumstance would have been at once detected. It was found, on the contrary, however, that the amount of this constituent was always minute, and, in some cases, nearly inappreciable, in the case of every sample taken. In the analyses of the raised coral-reefs from the Indian and Pacific Oceans, which Dr. SKEATS made on the materials supplied by Sir JOHN MURRAY, Professor ALEXANDER AGASSIZ, and Professor T. EDGEWORTH DAVID, calcium phosphate was found to exist generally as a mere trace. The highest proportions found were ·29 in a rock from Mango in the Fijis, ·064 in a rock from Ngillingillah in the same group, ·22 in a rock from Niue or Savage Island, and ·15 from rocks at Christmas Island.

From these results, compared with those quoted from HARRISON and other authors, it may be safely concluded that the rocks of Funafuti agree with most coral-reef formed limestones in containing only very minute traces of calcium phosphates—rarely if ever exceeding 0·2 per cent.

As is so well known from the examples at Christmas Island and the Clipperton Atoll, described by Mr. TEALL,* coral-island rocks which become the haunts of sea-birds may be covered with extensive deposits of guano, the water percolating through which may convert the underlying rocks into materials rich in phosphates, which are sometimes of great economical value.

A rock obtained by Professor SOLLAS from behind the Mangrove Swamp near Fongafale in the main island of the atoll was of a dark brown tint, and was found by him to be rich in phosphoric acid. The soil of the Taro plantation near this point had been collected by Mr. HEDLEY, and on analysis by Dr. COOKSEY† was found to contain 6 per cent. of phosphoric acid.

Analyses of two samples of rock brought from this locality by Professor SOLLAS yielded respectively 21·64 and 29·07 per cent. of calcium phosphate. In the islet of Avalau, lying north of the main island of Funafuti, two other specimens of a brown rock forwarded by Professor SOLLAS, yielded Dr. SKEATS on analysis 14·40 and

* 'Quart. Journ. Geol. Soc.,' vol. 54 (1898), pp. 230–232.

† Memoir III., Austral. Museum, Sydney, p. 76.

26·34 per cent. of calcium phosphate. The latter of these two rocks consisted of a brown matrix with white limestone fragments scattered through it. Enough of the brown matrix was isolated by careful picking by Mr. J. HENRY, in the Geological Laboratory, for analysis, and this yielded Dr. SKEATS 32·5 per cent. of calcium phosphate, while the white fragments gave only 5·79 per cent. of the phosphate.

As several islets on the western side of the atoll are haunted by sea-birds, it is not impossible that other surface rocks of Funafuti may be found to be phosphatised in a similar manner.

The fact that no phosphatised rocks were found in the borings, probably points to the conclusion that no part of the rocks traversed by the boring had been long elevated and exposed at the surface, so as to become impregnated with solutions of phosphates by the slow percolation of rain-water through the mass. It is in this way that rocks like those of Christmas Island and Clipperton Atoll probably become phosphatised, while rocks covered by guano, which are exposed to the action of the sea, do not appear to undergo chemical changes of the same kind.

7. PROPORTIONS OF CALCIUM AND MAGNESIUM CARBONATES IN THE FUNAFUTI ROCKS AS BEARING ON THEORIES OF DOLOMITISATION.

From what has been stated in the preceding pages, it will be seen that the rocks passed through in the borings at Funafuti are almost wholly composed of carbonates. As we have already stated, the organic matter of the plants and animals, everywhere small in amount, rapidly diminishes as we go downwards, and at the depth of 100 feet has almost entirely disappeared. The proportion of insoluble inorganic materials—as appears to be always the case with coral-reef rocks, when not in immediate proximity to volcanic or other foreign rocks—is so small as to be also almost inappreciable. The phosphates are present only in minute proportion, and no other substances occur except as the merest traces. Thus the great problem presented by these rocks is that which relates to the changes in the relative proportions of the calcium and magnesium carbonates and the causes to which these changes are to be ascribed.

As has been already pointed out, the proportion of magnesium carbonate rises in the first 50 feet of descent in all the borings, from the normal 1 to 5 per cent., up to a maximum of nearly 16 per cent., which is attained at a depth of about 25 feet, and then declines again to what may be considered the normal amount 1 to 5 per cent. At 637 feet the percentage of magnesium carbonate again rises from this normal and by 660 feet has reached nearly 40 per cent. This proportion with some small exceptions is maintained to the bottom of the bore-hole at 1114 feet (see fig. 23, pp. 364–5).

A series of analyses have been made of the materials in and around the Funafuti Atoll, with mineralogical studies of the rock at different depths from the bore-holes, and the bearing of these upon the question of the causes of the changes in the proportions of the two carbonates may now be discussed.

Various coral-reef rocks which have been analysed have yielded somewhat abnormal quantities of magnesium carbonate. Besides the early determination of magnesium carbonate in a rock from "Matea" (Makatea) in the Paumotus, by B. SILLIMAN, JUNR., we have a rock from Duke of York's Island, which yielded 1·808 per cent. to Professor LIVERSIDGE*; and a rock from Luamanif in Funafuti which yielded Dr. M. T. COOKSEY† 1·69 per cent. of magnesium carbonate.

In two specimens brought from Namuka in the Fiji Islands, by Mr. STANLEY GARDINER, Dr. POLLARD found respectively 6·7 per cent. and 21·5 per cent. of magnesium carbonate.‡ The interesting results obtained by Dr. SKEATS in his analyses of the rocks of raised reefs from various portions of the Indian and Pacific Oceans which have been made in the Geological Laboratory of the Royal College of Science, upon material supplied to us by Sir JOHN MURRAY, Professor A. AGASSIZ, and Professor T. EDGEWORTH DAVID, are of very great value.§

The only other case besides that of Funafuti in which it has been possible to obtain specimens collected in actual vertical sequence by boring operations, for the purpose of chemical analysis, is that of the deep boring made in 1895–96 at Key West, Florida. The results obtained by Mr. G. STEIGER in the laboratories of the United States Geological Survey, are as follows :—

Depth in feet.	Calcium carbonate.	Magnesium carbonate.
25	96·49	·61
100	96·47	1·61
150	97·12	1·80
350	91·91	3·51
600	87·28	5·25
775	83·12	14·07
1125	96·16	1·80
1325	97·31	1·30
1400	98·47	·63
1475	97·29	1·53
1625	96·27	2·39
1850	96·94	2·35
2000	96·48	2·22

As will be seen by comparison with the Funafuti results, though there is the marked rise of the magnesium carbonate percentage of 775 feet, there is nothing like so close an approach to complete dolomitisation as is found at Funafuti.

* 'Journ. Roy. Soc.' New South Wales, vol. 14 (1881), pp. 159–162.

† Memoir III., Austral. Museum, Sydney, Part 1, p. 76.

‡ 'Proc. Camb. Phil. Soc.,' vol. 9 (1898), p. 468.

§ Full details on this subject will be found in the Memoir by Dr. SKEATS published in the 'Bulletin of the Museum of Comparative Zoology of Harvard College' (vol. 42, 1903, pp. 53–126).

(*a*) *Amount of Magnesium Carbonate secreted by Plants and Animals to form their Skeletons.*

That the calcareous skeletons of plants and animals contain minute proportions of other salts, besides calcium carbonate, such as magnesium and iron carbonates, silica, fluorides, phosphates, &c., is a fact that has long been recognised. Among these adventitious substances the magnesium carbonate is usually the most abundant. The earliest attempt to make accurate determinations of the proportion of magnesium carbonate in the calcareous skeletons of plants and animals are those of FORCHHAMMER, whose pioneer researches upon the phenomena of dolomitisation are so well known.

By the year 1849, FORCHHAMMER had arrived at the conclusion, from numerous analyses, that the amount of magnesium carbonate in fresh animal and vegetable calcareous structures does not exceed 1 per cent. of their whole weight.* BENJAMIN SILLIMAN, JUNR., had already, in 1846, arrived at the conclusion, as we have seen in the preceding pages, that the proportion of magnesium carbonates contained in corals is small.†

That FORCHHAMMER's general conclusions were correct has been proved by many subsequent analyses by different chemists. Professor LIVERSIDGE in 1881 found in a reef-coral from the New Hebrides only ·17 per cent. of magnesium carbonate, but in a coral limestone from Duke of York's Island he found 1·808 per cent. of the magnesium salt.‡ In 1894 HÖGBOM analysed several corals from the Bermudas, obtaining the following results for the proportion of magnesium carbonate :—

Porites sp.	·62
Millepora alcicornis	·41 and ·97
Oculina sp.	·36
Coral from Java seas	·16

A number of univalves and bivalves from a coral reef yielded the same investigator an average of only ·16 of magnesium carbonate.§

Three analyses of different portions of the shell of the giant-clam (*Tridacna gigas*, L.) made in my laboratory, gave Dr. SKEATS percentages of ·36, ·44, and ·47 of magnesium carbonate.

WALTHER in 1885 obtained the following results from the analysis of forms belonging to two genera of Polyzoa :—‖

Eschara foliacea	1·2 of magnesium carbonate
Lepralia sp.	2·2 ,, ,,

* 'Oversigt over det Kongelige Danske Vidensk. Selskabs Forhandl.,' 1849, pp. 83–96; Bidrag til Dolomitensdannelshistorie; ERDMANN, 'Journ. Prak. Chem.,' vol. 49 (1850), pp. 52–64; 'Brit. Assoc. Rep.,' 1849 (part 2), pp. 36–37.

† 'Amer. Journ. Sci.,' 2nd series, vol. 1 (1846), p. 189, and 'United States Exploring Expedition' (Zoophytes), 1846, p. 712.

‡ 'Journ. Roy. Soc.,' New South Wales, vol. 14 (1881), pp. 159–162.

§ 'Neues Jahrb. für Min., &c.,' 1894, I, pp. 268–9.

‖ 'Zeitsch. d. Deutsch. Geol. Gesellsch.,' vol. 37, 1885, p. 338.

The first of these is said to have been quite fresh, the second was in fragments, and may have undergone some alteration.

The proportion of magnesium carbonate combined with the calcium carbonate of *Lithothamnion*, *Halimeda* and other calcareous algæ has been very variously stated by different authors.

In a specimen of *Halimeda* from Labuan, HÖGBOM found only a trace of magnesium carbonate; in a *Penicillus* from the West Indies, he obtained the same result.* A *Riviolaria* yielded ·69 of magnesium carbonate to 84·88 of calcium carbonates (·81 per cent.), while an undetermined calcareous alga from the Java seas gave ·04 of magnesium carbonate to 32·72 of calcium carbonate (·12 per cent.).

The very fresh tuft of *Halimeda opuntia* which was grown in six weeks at Funafuti (see p. 146) supplied the means of obtaining a very exact determination of the proportion of the two carbonates in a specimen which could have undergone little if any change. Dr. SKEATS' analysis of this specimen gave ·60 of magnesium carbonate to 86·50 of calcium carbonate (·7 per cent. of the total mineral matter).

(*b*) *Changes in the Proportions of the Calcium and Magnesium Carbonates which Occur after the Death of Calcareous Organisms.*

While there is good reason for accepting as correct the conclusion of FORCHHAMMER that living organisms, which secrete calcium carbonate in their skeletons, take up magnesium carbonate to the extent of, at most, only about 1 per cent. of the calcium salt, there is much evidence that many skeletons of dead organisms contain a considerably higher proportion of the magnesium salt, and the same is true of the muds, sands and rocks formed by the disintegration of the remains of these organisms.

In his 'Flora,' PAYEN gives an analysis of *Halimeda* showing 5·50 of magnesium carbonate to 90·16 of calcium carbonate,† which works out as 5·75 of magnesium carbonate in the total mineral matter. A specimen of dead *Halimeda* fronds from the Funafuti lagoon, which was analysed by Dr. CULLIS for me, gave 1·39 of magnesium carbonate to 98·32 of calcium carbonate, that is, the magnesium salt formed 1·4 per cent. of the whole mineral matter present.

A mass of *Halimeda* fronds, dredged from the face of the reef, off Tutanga, at a depth of between 50 and 60 fathoms, was analysed by Dr. SKEATS with the following result:—Magnesium carbonate was present to the extent of 4·0 per cent. to 93·59 of calcium carbonate, that is, the magnesium carbonate formed 4·1 per cent. of the total mineral matter.

The estimations made by Dr. SKEATS of the composition of the dredgings made on the floor of the lagoon of Funafuti, consisting of 90 per cent. and upwards of *Halimeda* fronds, showed from 2 to 6 per cent. of magnesium carbonate as being present. Similar results were yielded by the analysis of the materials in the Lagoon

* *Loc. cit.*, p. 273.

† PAYEN'S 'Flora,' vol. 1, p. 71.

Boring, there being little evidence that the proportion of magnesium carbonate increases in going downwards to the limit reached of 245 feet.

I have not been able to obtain any analysis of perfectly fresh *Lithothamnion*, but probably the fact that new living layers are constantly spreading over dead ones would make any result untrustworthy. Many chemists, however, have found in dead specimens of *Lithothamnion* a quite abnormal proportion of the magnesium carbonate. Thus GÜMBEL gave the proportion of magnesium carbonate to calcium carbonate in a specimen of *Lithothamnion nodosum*, KUTZ. sp., as 5·58 to 84·14, equivalent to a percentage of 6·62 of magnesium carbonate in the total carbonates,* this being the mean of several analyses. WALTHER in 1885 gave the composition of the mineral matter in a very compact species of *Lithothamnion*, as 3·99 of magnesium carbonate to 85·87 of calcium carbonate (= 4·44 per cent. of the mineral matter). A specimen of *Lithothamnion ramulosum* gave, to the same author, 6·42 of magnesium carbonate to 81·93 of calcium carbonate (= 7·15 per cent. of the mineral matter).†

Very striking, indeed, are the results of a similar kind obtained by HÖGBOM from the analysis of a considerable number of museum specimens of *Lithothamnion*.

These results may be tabulated as follows :—

Species.	Locality.	Calcium carbonate.	Magnesium carbonate.	Percentage of magnesium carbonate in mineral matter.
Lithothamnion, sp.	Java Sea	72·03	3·76	4·96
" "	Pliocene, Tarent	89·97	6·49	6·73
" "	Galapagos Is.	83·60	6·53	7·24
" "	Spitzbergen	84·83	8·07	8·69
" "	Honolulu	84·01	9·39	10·05
" *sorifern*	?	80·90	9·56	10·57
" *polymorphum*	Kattegatt	74·22	9·10	10·93
" sp.	Behring's Is.	74·24	9·94	11·82
" *racemus*	Naples	77·39	11·33	12·77
" *ramulosum*	"	63·00	9·46	13·05
" sp.	Bermudas	82·44	12·37	13·05
" *glaciale*	?	83·10	13·19	13·70

A specimen of *Lithothamnion Phillipi*, var. *funafutiensis*, FOSLIE, which retained in its outer layer the purple tint, usually so fugitive, and which was evidently collected in a living state, so far as this outer layer is concerned, yielded to Dr. SKEATS on analysis no less than 5·86 of magnesium carbonate. The mass was nearly 1 inch in thickness, and, except in the purple surface layer, was white and crumbling.

All these analyses point to the conclusion that the calcareous algæ, *Halimeda* and

* 'Abhandl. Bayer. Akad. Wissenchaft.,' vol. 11 (1871–74)), p. 26.

† 'Zeitsch. d. Deutsch. Geol. Gesellsch.,' vol. 37, 1885, p. 338.

Lithothamnion, which are now shown to play such an important part in the building up of coral-reef rocks, undergo rapid changes in their mineral skeleton after the death of the organisms. It is not improbable that the vegetable matter, so intimately united with the mineral substances, yields carbon dioxide during decay and decomposition, and that a solvent action goes on by which mineral matter is being continually carried away.

As we shall show, subsequently, there is good evidence that, when mixtures of the calcium and magnesium carbonates are slowly acted upon by weak solvents, the calcium carbonate is dissolved and carried away faster than the magnesium carbonate, leaving the whole, or nearly the whole, of the latter constituent behind. By this process of "leaching out" of the calcium carbonate from the mixed carbonates, the percentage of magnesium carbonate in the mineral skeletons must continually rise. It is by this *post-mortem* action that we may account for the high percentage of magnesium carbonate in the skeletons of *Halimeda*, *Lithothamnion*, &c., which has been discovered by PAYEN, WALTHER, HÖGBOM, and others, and has been thought by some authors to indicate a special capacity in these calcareous algæ for secreting the magnesium carbonate.

That this change, which takes place, perhaps, with especial facility in the case of the calcareous algæ, goes on in the case of other calcareous skeletons, we have abundant proof. Professor LIVERSIDGE found that, while in fresh coral the proportion of magnesium carbonate was very small, yet, in a coral limestone from Duke of York's Island, it amounted to 1·808 per cent. HÖGBOM, while proving that fresh corals contain in every case much less than 1 per cent. of magnesium carbonate, found in a coarse reef-rock 1·64 per cent.; in a reef-rock, with fragments of gastropods, 2·13 per cent.; in a white lagoon-mud, 1·79 per cent.; in a terra-cotta coloured lagoon-mud, 4·04 per cent.; while, in a coral-mud from the Java seas, 3·72 per cent. of magnesium carbonate was found present to 27·74 per cent. of calcium carbonate (= 11·12 per cent.).*

Very significant, too, is the fact which has been pointed out by Sir JOHN MURRAY and Mr. IRVINE, that in certain specimens of the giant-clam (*Tridacna gigas*, L.) a much higher percentage of magnesium carbonate was found in the outer and older portions of their umbos than in the internal and more recently formed shell-layers.†

(c) *The Action of Solvents upon Mixtures of the Calcium and Magnesium Carbonates.*

There has been much diversity of opinion among chemists as to the relative solubilities of the calcium and magnesium carbonates. From the behaviour of the two salts during ordinary analytical operations, it is generally taken for granted that the magnesium carbonate is much more soluble than the calcium carbonate; but, as

* *Loc. cit.*, p. 270.

† See 'Natural Science,' vol. 7 (1895), p. 22.

pointed out by the late Mr. E. T. HARDMAN, this seems only to be true when ammonium salts are present; while direct experiments, with solutions not containing the ammonium salts, give very different results.

In 1848 Professors W. B. and R. E. ROGERS described a series of experiments which they had made upon the solvent action of pure water, and of water containing carbon dioxide, on various minerals and rocks. By agitating powdered mixtures of the calcium and magnesium carbonates in flasks containing water with carbon dioxide, they found that the magnesium salt was dissolved faster than the calcium salt.*

A directly opposite result to this was, however, obtained by GUSTAV BISCHOF, from experiments described by him in his well-known 'Lehrbuch der Chemischen und Physikalischen Geologie.' In these experiments, magnesium limestones of known composition were finely powdered and mixed with water, through which carbon dioxide was passed for twenty-four hours. The liquids, when filtered off and analysed, yielded a considerable amount of calcium carbonate, but only traces of the magnesium carbonate. BISCHOF also suggests that dilute acetic acid behaves in the same way as carbonic acid, dissolving out calcium carbonate more rapidly than magnesium carbonate from a mixture of the two salts.†

The effect of even moderate pressure in modifying the solvent action of carbon dioxide on the magnesium and calcium carbonates is a fact well known to chemists. Based upon this principle, a process was for some time employed for the commercial extraction of nearly pure magnesium salts from dolomite, which consisted in subjecting the rock, when finely ground and mixed with water, to the action of carbon dioxide, *under a pressure of about four atmospheres.* Under these conditions the magnesium carbonate passed readily into solution while very little calcium carbonate was taken up.‡

HARDMAN, in 1876, repeated on a much more extended scale the experiments of BISCHOF, and proved conclusively that when magnesium limestones broken into small fragments are submitted to the slow action of water containing small quantities of carbon dioxide, the calcium carbonate is dissolved at a much more rapid rate than the magnesium carbonate.§

In 1894 it was shown by HÖGBOM,‖ that when calcareous organisms are treated with dilute acetic acid, the quantity of magnesium which passes into solution is very insignificant, as compared with the quantity of the calcium salt dissolved. He

* 'Amer. Journ. Sci.,' 1st series, vol. 5 (1848), pp. 401–405; also in 'Edinb. New. Phil. Journ.,' vol. 45 (1848), pp. 163–168; and 'Brit. Assoc. Rep.,' 1849, Pl. 2, pp. 40–42.

† 'Chemical and Physical Geology' (Cavendish Society), 1858, pp. 194–196.

‡ 'Dingl. Polyt. Journ.,' vol. 209, p. 467; abs., 'Chem. Soc. Journ.,' vol. 12, p. 96.

§ 'Roy. Irish Acad. Soc. Proc.,' 2nd series, vol. 2 (Science), pp. 705–730.

‖ 'Neues Jahrb. für Min.,' &c. (1894), vol. 1, p. 271. The first author who suggested this enrichment of a rock with magnesium salts by the gradual leaching out of calcium salts appears to have been GRANDJEAN, in his Memoir on "Die Dolomite und Braunstein-Lagerstätten im untern Lahnthal," 'Neues Jahrb. für Min.,' &c. (1844), pp. 543–553.

found that a specimen of *Lithothamnion*, which contained about 11 per cent. of magnesium carbonate, when treated with acetic acid till about 60 per cent. of the mineral matter was removed, had become enriched with magnesium carbonate to the extent of 20 per cent., owing to this more rapid leaching out of the calcium carbonate. In the same way it was found by HÖGBOM that a coarse lagoon-mud treated with acetic acid, till 80 per cent. of the material was removed in solution, gave the following result. Before treatment the percentage of magnesia present was 1·79 per cent. and afterwards as high as 4·4 per cent.

Indirectly, however, we have abundant evidence that under the solvent action of carbon dioxide a leaching out process takes place in mixtures of the calcium and magnesium carbonates, and the former being dissolved more rapidly than the latter, the magnesium percentage in the residue constantly rises.

In connexion with this point the very valuable Memoir of Professor E. J. GARWOOD, 'On the Origin and Mode of Formation of the Concretions in the Magnesian Limestone of Durham,'* a Memoir which has perhaps not received the attention which it deserves, has a very important bearing on the subject under discussion. Professor GARWOOD shows that the curious concretions so well-known for their simulation of organic form, are the result of the solvent action of water containing carbon dioxide upon a mass containing various proportions of the calcium and magnesium carbonates, up to 46 per cent. of the latter salt. The concretions, however, consist almost entirely of calcium carbonate, the proportion of magnesium carbonate being only from 1·5 to 4 per cent. It is evident, therefore, that in the solvent action it is the calcium salt which is taken up almost to the exclusion of the magnesium salt.

HÖGBOM'S analysis of stalactites taken from caves in the coral rocks of the Bermudas entirely confirm the results and reasoning of Professor GARWOOD. He found that these stalactites—clearly formed by the percolation of water with carbon dioxide through the coral-rock—contained only ·18 to ·68 per cent. of magnesium carbonate, while the coral-rock itself contains about five times that percentage of the magnesium carbonate.†

HÖGBOM'S researches on the composition of the marine laminated marls of Sweden, which are deposited from water (formed by the melting of the inland ice), after it has flowed over the Silurian rocks of the country, are of especial interest and value in connexion with this question. He shows that as we proceed farther and farther from the limestone rocks the proportion of the carbonates to argillaceous matter regularly diminishes. If, however, we compare the relative proportion of the calcium and magnesium carbonates in the Silurian limestone with that in the sediments derived from them, a very remarkable and significant difference is detected. While the proportion of magnesium carbonate in the Silurian limestone is only about the one-hundredth part of the calcium carbonate, the laminated marls yield from 3 per

* 'Geological Magazine,' Dec. 3, vol. 8 (1891), pp. 433–446.

† *Loc. cit.*, p. 271.

cent. upwards of magnesium carbonate, until at last we find materials in which the calcium carbonate has entirely disappeared. As the amount of mixed carbonates in the mud diminishes, the proportion of magnesium carbonate to calcium carbonate is found to rise.

The analyses made of the laminated clays for the Geological Survey of Sweden afford the means of making a very exact comparison of the changes taking place as we proceed from north to south, from Gefle to the south of Stockholm, that is, going farther and farther from the Silurian limestone of Bothnia. The results are so striking and conclusive that I transcribe the table as given by HÖGBOM, the localities in which are situate from north to south:—

Localities.	Percentage of calcium carbonate.	Percentage of magnesium carbonate.	Percentage of magnesium to calcium carbonate.	Number of analyses.
Leufsta	32·0	1·2	3·7	14
Örbyhus	23·0	1·4	6·1	6
Salsta	21·7	1·5	6·9	10
Upsala	17·8	1·3	7·2	8
Sigtuna	11·4	0·8	7·0	29
Fånö	11·9	1·9	16·0	9
Södertelje	7·6	2·8	37·0	9
Hörningsholm	3·3	1·2	36·0	17

These analyses show conclusively that as the detritus from the Silurian limestone is carried out into the Baltic, the soluble constituents are gradually dissolved out of it, but that in this solvent action the removal of calcium carbonate goes on much more rapidly than that of the magnesium carbonate, so that a material becoming gradually richer in the last-named constituent is formed and left behind.

The observations made in the "Challenger" and other deep-sea explorations—which have been discussed in the memoirs of Sir JOHN MURRAY, Professor RENARD, Mr. ROBERT IRVINE* and others—prove conclusively that, as materials descend into the deeper parts of the ocean, calcium carbonate is being continually abstracted by the solvent action of carbon dioxide. This is well illustrated by the table on the next page given by MURRAY and IRVINE on the proportion of carbonates in deep-sea deposits, which are based on the "Challenger" analyses.

The study of deep-sea oozes all over the world has amply verified the results obtained during the voyage of the "Challenger," as to the constant solution of the skeletons of organisms consisting of calcium carbonate in their descent from the surface waters to the lower depths of the ocean.

* MURRAY and RENARD, "Challenger" Reports, 'Deep Sea Deposits,' (1891); MURRAY and IRVINE, 'Roy. Soc. Edin. Proc.' (1889), vol. 17, p. 89; MURRAY and IRVINE, 'Roy. Soc. Edin. Trans.,' vol. 37, (1893), p. 481.

Depths in fathoms.	Mean percentage of carbonates.	Number of analyses.
Under 500	86·04	14
From 500 to 1000	66·86	7
„ 1000 „ 1500	70·87	24
„ 1500 „ 2000	69·55	42
„ 2000 „ 2500	46·73	68
„ 2500 „ 3000	17·36	65
„ 3000 „ 3500	0·88	8
„ 3500 „ 4000	0·00	2
Over 4000	trace	1

HÖGBOM has shown conclusively by a discussion of these same "Challenger" analyses* that, under the action of the carbon dioxide in sea-water, the calcium carbonate passes into solution much more rapidly than the magnesium carbonate. This fact appears most strikingly apparent from the following table, which is taken from HÖGBOM'S suggestive Memoir :—

Limits of carbonates.	Mean calcium carbonate.	Mean magnesium carbonate.	Percentage of magnesium carbonates to calcium carbonate.	Number of analyses.
80 to 100 per cent. . .	86·7	0·7	0·8	8
60 „ 80 „ . .	68·3	1·4	2·0	8
40 „ 60 „ . .	52·0	1·2	2·4	8
20 „ 40 „ . .	32·0	0·9	3·0	3
10 „ 20 „ . .	16·2	1·6	10·0	4
5 „ 10 „ . .	6·1	0·7	11·5	1
3 „ 5 „ . .	3·7	1·6	43·0	7
1 „ 3 „ . .	2·0	2·1	105·0	9

It is evident from a comparison of the two tables given above that, under the conditions which exist in the open sea, the carbonates are being gradually dissolved out of materials as they slowly descend to the floor of the deep ocean, and also that the calcium carbonate is being more rapidly removed in solution than the magnesium carbonate.

The experiments and observations which have been described point to the conclusion that the relative solubilities of the calcium and magnesium carbonates in water containing carbon dioxide may vary greatly under different conditions of temperature, pressure, and the presence of other salts in the solution. That, in many parts of the ocean, conditions prevail which tends to the leaching out calcium carbonate, and the

* 'Neues Jahrb. für Min.,' &c., 1894, vol. 1, p. 262.

consequent accumulation of the magnesium carbonate, there cannot be any doubt, but the exact nature of these conditions has not yet been determined.

(*d*) *Bearing of the Analyses made of the Funafuti Materials, upon the question of the Causes of Dolomitisation in Coral-Reef Rocks.*

It has been conclusively shown by modern researches—as pointed out in the preceding pages—that the free carbon dioxide in ocean waters exercises a solvent action upon all carbonates carried down to the sea in suspension, as well as upon the calcareous skeletons of plants and animals which have lived in the ocean and have derived the materials of their skeletons from its waters. How far this solvent action has been aided by the great pressure in the deeper parts of the ocean has not been determined. Neither has the influence of temperature been exactly ascertained, though the examples of altered *Lithothamnion* cited from Arctic regions (see p. 377) prove that even in waters only a little above the freezing point solvent action is taking place.

This solvent action goes on more rapidly in the skeletons of those organisms which are composed of the unstable aragonite than in those which consist of the more stable calcite; and where the skeleton consists in parts of different forms of calcium carbonate, the aragonite portions are removed more rapidly than the calcite portions.

It has been pointed out that in those organisms of loose texture, like corals and calcareous algæ, or those which contain much organic tissue combined with the mineral matter of their skeletons, like fish and crustacean skeletons, the work of solution appears to go on more rapidly than in the case of skeletons of compact texture with little organic matter, like some of the foraminifera. As Sir JOHN MURRAY and Mr. IRVINE remark :—

"All those shells in which a considerable quantity of organic tissue is associated with the carbonate of lime disappear in solution more rapidly than the shells of the Foraminifera which contain little organic matter. During the whole of the 'Challenger' cruise only two bones of fishes, other than the otoliths and the teeth, were dredged from the deposits, and all traces of the cetacean bones were removed, except the dense ear bones, and the dense ziphioid beaks. The remains of crustacean animals were almost wholly absent from deep-sea deposits, with the exception of ostracod shells and the hard tips of some claws of crabs."*

There can be little doubt that this result is due to the circumstance that the slow decay and oxidation of the organic tissues must produce carbon dioxide in the most intimate admixture with the carbonates, and that under these conditions solution proceeds rapidly.

There is reason to believe that this solvent action goes on with especial rapidity in the case of the calcareous algæ, *Lithothamnion* and *Halimeda*, which are now

* 'Roy. Soc. Edin. Proc.,' vol. 17 (1889), p. 99.

known to play such an important part in building up of coral-reef rocks. The former of these organisms, a purple seaweed, secretes the calcium carbonate in the form of calcite; the latter, a green siphonaceous form, has its skeleton composed of aragonite.

It is now quite certain, both from the results of experiment and observation, that in this solution of the carbonates—alike in organic and in inorganic sediments—the calcium carbonate is, as a rule, much more rapidly removed than the magnesium carbonate. The effect of this continual *leaching out* of the calcium carbonate is to leave behind residues which become progressively richer in the magnesium carbonates. This appears to be true of all oceanic deposits containing carbonates, though there is evidence that certain organisms, like the corals and other forms consisting of aragonite or containing much organic tissue, and especially the calcareous algæ, undergo solution, and consequently the leaching-out process, more rapidly than others.

How far the enrichment of a material with magnesium carbonate by the constant leaching out of the calcium carbonate may proceed has not been exactly determined. But the analyses of different forms of *Lithothamnion* by HÖGBOM show that specimens of that organism, which probably contained originally not more than 1 per cent. of magnesium carbonate, may have the calcium carbonate leached out till the proportion of magnesium carbonate rises to 14 per cent. (see p. 377). It is obvious that in this leaching-out process the density and solidity of the mass of carbonates must be greatly reduced, and the appearance of many of the remains of these calcareous algæ indicates that much of the mineral substance of their skeletons has been removed by solution.

In the cores from the borings at Funafuti we have seen that, over a very considerable area, there is evidence that down to the depth of 15 to 25 feet there is a tolerably rapid rise in the percentage of magnesium carbonate up to 16 per cent. and then a decline at nearly the same rate down to 50 feet. In the case of the Main Boring two maxima of 16·4 and 16 per cent. of magnesium carbonate can be detected at depths of 15 and 25 feet respectively, with a minimum of 12 per cent. between them. In the two borings made by Professor SOLLAS, although we have not the means of tracing so accurately the rate of rise and fall of the magnesium carbonate percentage, we have clear evidence that a similar condition of things exists.

It seems not improbable that the enrichment of the rock in magnesium carbonate up to 16 per cent. in the upper part of the cores may be entirely due to the leaching out of the calcium carbonate. Of this we are able to supply an interesting confirmation from the microscopic examination of the cores by Dr. HINDE and Dr. CULLIS. The degree of mineralisation in this part of the core is described by the former as being slight, and Dr. CULLIS, whom I asked to look very carefully in this part of the core for indications of dolomite, assures me that he has failed entirely, either by microscopical or chemical tests, to detect any trace of the formation of crystals of that mineral in this part of the core.

From these facts, then, it seems not unfair to conclude that in the upper part of

the core the rise in the proportion of the magnesium carbonate may be entirely due to the leaching out of the calcium carbonate.

If this conclusion be accepted as a correct one, we have probably an indication of the limits of the variation in the proportions of the two carbonates which can be brought about, by the leaching-out process, in materials of this kind. As more and more of the calcium carbonate is removed, the remaining mass must lose its cohesion, form, and minute structure, and after a certain limit has been passed only a small quantity of amorphous material will be left behind.

From the examples of the *Lithothamnion* cited by HÖGBOM and the study of the upper portion of the Funafuti cores, we are probably justified in concluding that the enrichment of a mass of mixed carbonates with the magnesium salt may go on to the extent of 14 to 16 per cent. at least—without, on the one hand, the introduction of magnesium salts from without, or, on the other hand, the entire obliteration of the organic structure of the mass. From a depth of 50 feet to one of 637 feet, in the boring, the percentage of magnesium carbonate varies within small limits (1 to 5 per cent.). These small differences may not improbably be due to the varying proportion of organisms which differ in their susceptibility to the leaching-out process. At all events, all the changes in the percentage of the magnesium carbonate may be easily accounted for in this way.

It is to be noticed, moreover, that through a considerable portion of this descent, from 50 to 637 feet, the material available for analysis consisted only of the comminuted fragments, largely made up of remains of foraminifera, washed out of the bore-hole, like sand, during the operation of the diamond-drill. It is doubtful how far the analyses of this comminuted material can be taken as representing the composition of the whole rock passed through. It is not improbable that the parts in which most solvent action had taken place had been reduced to a more friable condition, and these portions, especially rich in the magnesium carbonate, would be carried away in a very finely-divided state.

But, at a depth of 637 feet, we begin to meet with quite new conditions. Instead of an extremely cavernous and friable rock, which, by the action of the diamond-drill, is reduced to a more or less coarse powder, we get a white, chalky-looking material, which is brought up in fairly solid cores, and is found to contain a high percentage of magnesium carbonate. This proportion rises rapidly, till at 660 feet it reaches the limit of 40 per cent.

Under the microscope, however, this rock, which has undergone such profound chemical and mineralogical change, is found to consist of precisely the same organisms as those found in the lower portions of the core. *Halimeda* and *Lithothamnion* are very abundant, and the usual species of foraminifera and corals everywhere occur in the rock. At a depth of about 763 feet this soft, friable rock passes gradually into one of considerable hardness and density, but from time to time there is a recurrence to the softer and more friable type. In this part of the core we find

that, not only are many of the organisms reduced to the condition of casts, but that in the hollow spaces of the rock, new chemical deposits, encrusting the sides of hollow spaces, and sometimes filling them up, have been formed.

In seeking to account for the pseudomorphic changes which have taken place in this coral-rock, it is obvious that we are limited to one of three hypotheses, or to a combination of two or more of them. These are as follows :—

(*a*) The solution of calcium carbonate at a greater rate than of the magnesium carbonate, by which the percentage of the latter salt will gradually rise.

(*b*) The introduction of magnesium carbonate from without, filling up the cavities of the rock, or entering into combination with the calcium carbonate, so as to produce a double salt.

(*c*) An interchange of the two bases between the rock and the surrounding sea-water, whereby a portion of the calcium in the carbonate passed into solution and is replaced by magnesium, thus tending to form the double salt of dolomite at the expense of calcite or aragonite.

We have already considered the first of these alternative hypotheses, and have shown that there is good ground for concluding that a process of leaching out of calcium carbonate does go on in the waters of the ocean, especially in the case of certain classes of organisms, and under particular conditions. But we have also seen that there is a probable limit beyond which this action cannot go on without entirely destroying, or rendering unrecognisable, the organic or other structures in the mass. We have suggested that this limit may probably be nearly reached when the percentage of magnesium carbonate has been raised from 1 to 14 or 16 per cent.

It is clear then that we must look to another cause to explain the much greater rise in the proportion of magnesium carbonate which takes place in the lower portions of the core (637–1114 feet) up to 40 per cent. and upwards. Without affirming that a direct deposition of magnesium carbonate from sea water is not possible, most chemists will be disposed to regard it as more probable that a portion of the calcium in the calcium carbonate has been gradually replaced by magnesium.

What are the exact conditions under which these interesting chemical changes take place is a problem of great interest, but at the same time one of which it is very difficult to suggest a satisfactory solution. I have consulted Dr. SORBY, who has for so many years directed his studies to this and similar questions. He has been good enough to examine a series of slides from the different cores, and has written a note on the subject.*

At the same time I have arranged that Dr. CULLIS, following the methods so admirably inaugurated by Dr. SORBY,† and aided by modern methods of micro-chemical analysis, should make a very thorough and detailed study of all the cores

* See Section XIII (p. 390).

† 'Quart. Journ. Geol. Soc., Proc.' (Anniversary Address for 1879), vol. 35, pp. 46–92.

from top to bottom, and the results of this investigation are also added in a separate report.*

There is one class of processes, with which geologists are very familiar, as taking place very slowly but very certainly in great rock masses that are permeated and traversed by weak solvents, the action vaguely referred to as "segregation."

Nothing is more certain than the conclusion that rocks which contain minute quantities of silica, iron disulphide, or the iron, calcium or magnesium carbonates, diffused through their mass, may have those materials collected into nodules and sometimes into masses of considerable size, by this "segregative" action. In many, perhaps in all cases, the centres of this segregative action are determined by the presence, in the first instance, of a somewhat higher percentage of the particular substance at certain spots. Thus, in the chalk, which consists of a mass of calcareous organisms, plant and animal, through which were diffused, at first, a number of skeletons of the organisms that secrete colloid silica—sponge spicules, radiolarian skeletons, and diatomaceous frustules—the colloid silica passes into solution, and appears to be attracted to those portions of the mass in which an abnormally high portion of silica happens to be present, as in the remains of siliceous sponges. In this way the nodular masses of flint are formed, the nodules growing irregularly till all the free silica has been absorbed into them. This silica replaces the calcium carbonate at the spots where it is collected, pseudomorphs in colloid silica being formed of the *Globigerina* and other calcareous skeletons which make up the chalk, and the interspaces filled up with the same colloid silica. Ultimately the colloid silica tends to pass into the more stable crystalline form (quartz) and we thus obtain that form of chalcedony—composed of mixtures in varying proportions of quartz and opal (colloid silica)—which we call flint.

Precisely similar changes take place in sandstones, clays, limestones, &c., in which are diffused small quantities of iron disulphide, and the various carbonates or other mineral substances. A concentration of the material begins, usually, around some fossil, and this goes on till the whole organism is mineralised and is afterwards continued till a nodule, completely enveloping it, is formed.

We have seen that the leaching-out process in organic structures containing the two carbonates, consequent upon the greater solubility of the calcium carbonate, as compared with the magnesium carbonate, is continually going on in the waters of the ocean. In this way a material is formed in which the percentage of magnesium carbonate may rise up to 16 per cent. or possibly more. Now this mass in a coral reef is everywhere permeated and acted upon by sea-water, containing a very notable proportion of magnesium, principally in the condition of chlorides and sulphates. May not these materials, enriched by the magnesium carbonate, exercise an attractive action on the magnesium salts of the ocean waters, giving rise to double decomposition and the gradual replacement of a part of the calcium in the carbonates by magnesium?

* See Section XIV (p. 392).

If this be the explanation of the dolomitisation of coral-reef rocks, there is still much that demands investigation. As shown by the study of the Funafuti materials, and by the various rocks collected from numerous upraised reefs by Sir JOHN MURRAY, Professor A. AGASSIZ, and Professor T. E. DAVID in the Indian and Pacific Oceans, the dolomitisation of rocks is by no means constant or uniform in its action. While certain portions of a reef may contain a high percentage of magnesium carbonate, other parts of the same reef may be almost free from that salt, and the reasons why some parts of the mass are almost completely dolomitised, while other parts remain chemically unchanged, is by no means obvious.

mechanical of the rock and water [illegible]

We have seen that down to the depth of 637 feet the degree of enrichment of the rock by magnesium carbonate may be probably ascribed to the leaching out of calcium carbonate. In this part of the core we have no examples of the formation of crystals of dolomite in the mass. But in the lower part of the boring the formation of dolomite crystals throughout the mass has gone on to a greater or less extent, either at the expense of the calcite of the original organisms or of the deposits of that substance as mud or crystals within and around the organisms.

It by no means follows that, because the dolomite crystals are only found at considerable depth, the action to which the formation of those crystals was due took place only at this depth. The action may possibly have taken place at or near the surface, and the rock have subsided after its alteration. At the same time, it may be noted that all the rocks now at short distances from the surface in Funafuti show no dolomite crystals, and contain only such an amount of magnesium carbonate as may be accounted for by the leaching-out process.

The different proportions of magnesium carbonate which occur in this lower part of the boring, may evidently be accounted for in many cases by the varying amount of calcite organisms (foraminifera, &c.) which do not lend themselves readily to the leaching-out process, and of algæ, corals, &c., which are probably much more susceptible to this action. It is doubtful, however, whether the very considerable falling-off in the percentage of magnesium carbonate between 819 and 875 feet, and between 1050 and 1097 feet, can be altogether accounted for in this way.

It is very noteworthy that, high as the percentage of magnesium carbonate rises—up to and even beyond 40 per cent.—it never reaches the limit of nearly 46 per cent. required for the conversion of the whole mass into the double carbonate. This limit is represented by the dotted line in the diagrammatic section (fig. 23, pp. 364–5). The highest percentage of magnesium carbonate (43 per cent.) was found at a depth of 950 feet. It has been suggested to me by Professor ARMSTRONG that possibly there may exist resting limits in this replacement of one base by another in the mixed carbonates, more stable points being reached from time to time. On the other hand, the resistance which some calcite organisms appear to offer to chemical change may account for the result—there being, apparently, almost always some remains of unaltered organisms. It is noteworthy that, among the rocks of the earth's crust,

perfect dolomites are much rarer than "magnesian limestones," or rocks in which the proportion of magnesium carbonate present is insufficient for the conversion of the whole rock into the double salt.

From what has been said, it will be apparent that, while the investigations that have been carried on upon the materials obtained in the vertical borings of Funafuti and also on specimens obtained from upraised reefs in the Indian and Pacific Oceans, show that the dolomitisation of coral reef-rock, first demonstrated by the researches of DANA and SILLIMAN, really takes place sporadically over very wide areas, the exact conditions under which the operations occur still call for careful investigation both by observation and experiment.

The separation of the two carbonates from sea-water, to form double salts, may be possibly determined by complex relations, like those which VAN'T HOFF and his pupils have shown to govern the separation of the various salts which form the Stassfurt deposits. It is satisfactory to know that this problem, as it affects the two carbonates, is now engaging the attention of a chemist, Dr. E. F. ARMSTRONG, who has already had considerable experience in this field of inquiry.

SECTION XIV.

THE MINERALOGICAL CHANGES OBSERVED IN THE CORES OF THE FUNAFUTI BORINGS.

By C. GILBERT CULLIS, *D.Sc.*, *F.G.S.*

CONTENTS.

1. INTRODUCTION.

THE minerals which occur as the recognisable constituents of the Funafuti cores are calcite, aragonite and dolomite.

The small amount of calcium phosphate, which analysis shows to be present in all parts of the boring, is probably included within these, as an invisible impurity; it has not been detected as a distinct mineral. The possibility of the occurrence of magnesite, in certain of the rocks, has not been overlooked, but no evidence that magnesium carbonate exists in them, otherwise than in combination with calcium carbonate, has presented itself.

The discrimination between calcite, aragonite and dolomite, in thin sections of the rocks of modern coral reefs, which consist so largely of fresh calcareous organisms, and in which such crystals as occur are generally of microscopic dimensions, is not always a simple matter; it is most readily effected by micro-chemical methods. Of these there are two which are of special value, and which have been used with the most satisfactory results in the present investigation. The first is that of MEIGEN,*

* 'Centralblatt für Mineralogie,' 1901, pp. 577, 578.

by means of which aragonite, if present in a section, is stained, while calcite and dolomite remain unstained. The second is that of LEMBERG,* by which calcite and aragonite are stained, while dolomite remains unstained. The former method serves for the differentiation of aragonite from calcite and dolomite; the latter for that of dolomite from calcite and aragonite (see Plate F).

The value of these two tests is increased by the fact that they provide a simple and trustworthy means of determining the mineralogical nature, not only of the well-crystallised inorganic portions of the rocks, but also of the original calcareous organisms. Concerning the organisms of the Funafuti reef—as exemplified in the rocks of the boring—the tests have given the following results. Those composed of aragonite, are the calcareous alga *Halimeda*, the Madreporarian corals, the alcyonarian genus *Heliopora*, the hydrocorallines, the majority of the mollusca, and the minute spicules of tunicates. The rest are of calcite, and comprise the calcareous algæ *Lithothamnion* and *Lithophyllum*, the foraminifera, the polyzoa, the echinodermata, and the spicules of alcyonaria. These results, so far as they go, are in agreement with those obtained in the first instance by Dr. H. C. SORBY,† and by numerous investigators later.

The calcite and aragonite of which the various organisms are composed may be spoken of as *primary* calcite and aragonite; that which makes its appearances in the rocks after their accumulation will be referred to as *secondary* calcite and aragonite. No such distinction is necessary in the case of the dolomite, since it is always of secondary origin.

The distribution of these three minerals in the boring is noteworthy. Aragonite is confined to the upper cores, and dolomite to the lower, while calcite, which is the sole constituent of the middle cores, is also found above and below, in association with aragonite on the one hand and dolomite on the other. Dolomite is not encountered in a clearly individualised form, until a depth of between 637 and 638 feet has been reached; below this it continues, in varying amounts, to the bottom of the boring. It may be merely a coincidence, or it may be a fact of special significance, that in none of the cores has aragonite been found in association with dolomite.

2. THE MINERALOGICAL CHARACTERS OF THE ROCKS OCCURRING BETWEEN THE SURFACE AND THE DEPTH OF 637 FEET.

The rocks included within these limits are limestones, which contain, as a rule, only a small proportion of magnesium carbonate; but within the first 50 feet they carry a higher proportion than usual of this constituent, which attains a maximum of 16 per cent. at the depth of 25 feet. From that point, both upwards and downwards, the percentage of magnesium carbonate decreases, till it reaches its normal

* 'Zeitsch. Deutsch. Geol. Gesellsch.,' 1888, vol. 40, p. 357.

† Presidential Address, 'Quart. Journ. Geol. Soc.,' 1879, vol. 35, Proc. pp. 58—66.

small proportion at the surface, on the one hand, and at the depth of about 50 feet, on the other.

This rise in the proportion of magnesium carbonate in the first 50 feet of the boring was ascertained by chemical means. It could not have been discovered by means of the microscope; unstained sections show nothing that can be identified as dolomite, while sections treated with LEMBERG'S solution stain uniformly, as they would if composed of calcium carbonate only. Well-defined dolomite is not present in these rocks; although magnesium carbonate has been introduced into them in considerable amount, it has, so far, failed to cause the molecular rearrangements necessary for the formation of the crystallised mineral. The horizon is one of interest and importance, inasmuch as it affords evidence that partial dolomitisation, at least, may be effected at no greater depth than 25 feet from the surface of the sea, and that magnesium carbonate may enter into the constitution of the rocks of coral-reefs, to the extent of 16 per cent., without causing the formation of individualised dolomite.

The rocks of the first few feet of the boring consist only of the original organisms of calcite and aragonite, and the products of their wear and tear, but limestones of this simple original character constitute but a small proportion of the rocks of the boring, and include only those quite recently deposited. As the cores are examined in descending order, various secondary characters make their appearance owing to the addition of new matter to the rocks, or the modification, in various ways, of that of which they were primarily composed. Of these changes, three, which are the most important to be observed in the first 637 feet of the boring, will be briefly described:—

a. The deposition of secondary calcite and aragonite from solution.
b. The crystallisation of the finely-divided calcareous detritus.
c. The disappearance of aragonite.

a. The Deposition of Secondary Calcite and Aragonite from Solution.

In the most recent rocks of the boring, a large proportion of the interspaces between the various organisms (and a still larger proportion of those within them) are seen to be quite empty; but as successively deeper cores are examined, these empty cavities are observed to be the sites of deposition of secondary calcite and aragonite.

Of these two minerals, calcite is the one which is deposited more frequently and in greater relative amount. Normally, it would seem, calcite is deposited upon calcite organisms, and aragonite upon aragonite organisms; but this is not invariably the case, for not only is calcite found in all cavities bounded by calcite organisms, but it is also found in a considerable proportion of those bounded by aragonite organisms. Aragonite, on the other hand, is never deposited upon organisms of calcite, and only upon those of aragonite which are composed of well-marked crystalline elements, these elements seeming to exercise a determining influence upon the calcium carbonate being

thrown down from solution, and to cause it to be deposited in a molecular form identical with their own. Moreover, it is only upon such surfaces of these organisms as are clean that the deposition of aragonite takes place, the intervention of the thinnest film of mud being sufficient to destroy the influence of the organic fibres, and to cause the precipitation of the more readily formed calcite. This is probably the reason why the secondary aragonite deposited from solution is practically confined to the cavities within the organisms, and is rarely, if ever, found upon the limiting surfaces of the interspaces between them.

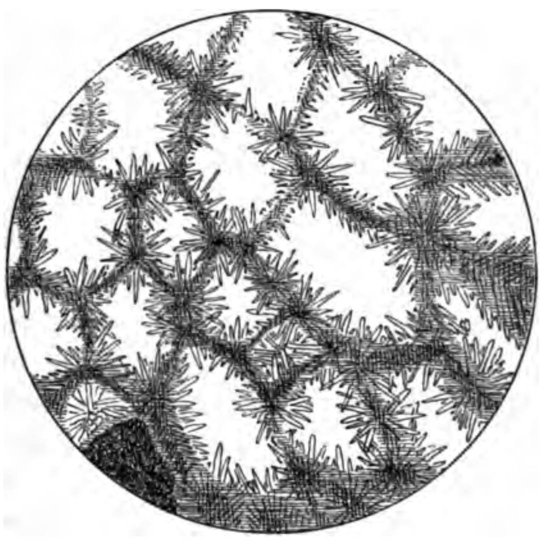


Fig. 24.—Main Boring. Core 28. Depth 27 feet. × 90.

Transverse section of *Heliopora*, showing the deposition of secondary aragonite in continuity with the primary aragonite of the coral.

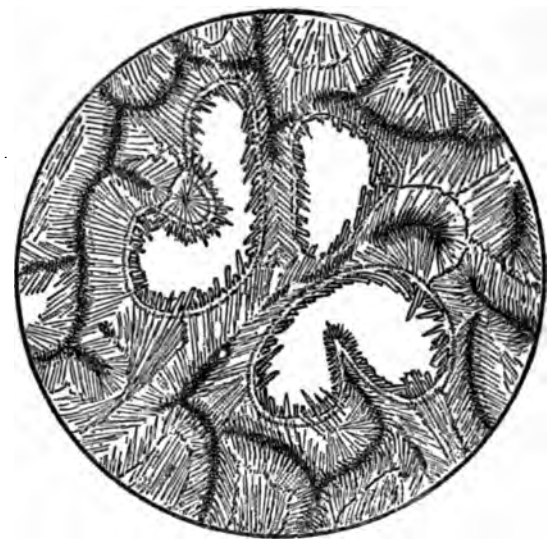


Fig. 25.—Main Boring. Core 83, Depth 68 feet. × 150.

Coral showing commencement of deposition of aragonite in empty cavities. The "dark line" in the coral substance is well seen, but its preservation at this depth is somewhat unusual.

As a rule, the deposits of secondary calcite and aragonite show a marked relation to the structural elements of the organisms which they invest. The crystals of aragonite are invariably deposited in continuity with the fibres of aragonite organisms (figs. 24, 25, 26, 29, 52, &c.), while those of calcite are generally, but not always, continuations of the elements of calcite organisms (figs. 30, 39, 40). When calcite is deposited upon an aragonite organism, it need hardly be stated, no such crystalline continuity is established (fig. 29).

It will be gathered from what has just been said, that whereas aragonite is deposited in one form only, calcite is not. The calcite deposits are, in fact, of two markedly different types. The first of these, which will be referred to as the fibrous encrusting deposit, consists of densely packed minute prismatic elements, which are so arranged as to impart to it a fibrous structure (figs. 26, 27, 28, 53; Plate F, figs. 1, 2). It often exhibits a concentric structure also, due to differences in the nature of its successive layers; the darker layers owe their inferior transparency to the presence of

fine calcareous "mud," which is absent from those that are perfectly clear, and which must have been intermittently present in the waters from which the deposit was precipitated. In no case are the elements of this fibrous deposit disposed in continuity with the structural elements of the organisms invested; it is as though their deposition had proceeded too rapidly for the necessary molecular adjustments to be made.

Fig. 26.—Main Boring. Core 13. Depth 10–20 feet. × 100.

Coral with cavities containing calcite and aragonite. The cavities on the left are filled with secondary aragonite, the crystals of which are continuous with the adjacent coral fibres. The cavities which are only partially filled contain secondary calcite of the fibrous encrusting type, the elements of which, in all cases, spring perpendicularly from the cavity walls.

The distribution of this type of deposit is remarkable. In the first of the borings made under the direction of Professor SOLLAS, it has been detected at various points between 30 and 80 feet; in the second at a number of depths from about 20 feet down to the bottom of the boring (72 feet). In the Main Boring it occurs, and is abundant between the depths of 20 and 30 feet, and is also seen in small amount for a little distance above and below these limits. In other words it occurs at that horizon, in this upper part of the boring, at which the proportion of magnesium carbonate is unusually high. A similar, if not identical deposit is conspicuous in the rocks of the lowest 300 feet of the boring (figs. 44, 45, 46, 48, 49, 67, 68, 69, and Plate F, figs. 4, 5, 6), rocks again in which the proportion of magnesium carbonate is high.

The other type of secondary calcite consists of crystals which, though actually of small dimensions, are usually relatively large and well developed compared with those of the fibrous deposit. They are clear and transparent, and their apices, which project into the cavities which they line, often exhibit well-defined crystal faces (figs. 29, 33, 36); moreover, whenever they invest a calcite organism which possesses a marked crystalline texture, they are disposed in optical continuity with its structural elements (figs. 30, 39, 40; Plate F, figs. 3, 4). This more perfectly crystallised type of secondary calcite, the characters of which suggest that it may have been formed more slowly than the fibrous type, is abundant in the boring from below 30 feet down to 637 feet, and occurs occasionally also at greater depths.

These various deposits of secondary calcite and aragonite furnish a crystalline cementing material by which the original organisms and organic fragments of the rock are bound together, and the cavities, within and between them, more or less completely filled up.

Fig. 27.—First Boring (Sollas). Depth 30–80 feet. × 30.

"Coral-reef sand" cemented by fibrous encrusting calcite. The minute prismatic elements of the deposit are not disposed in crystalline continuity with the calcite organisms. Compare the investments of the urchin-spines in this figure and in fig. 30.

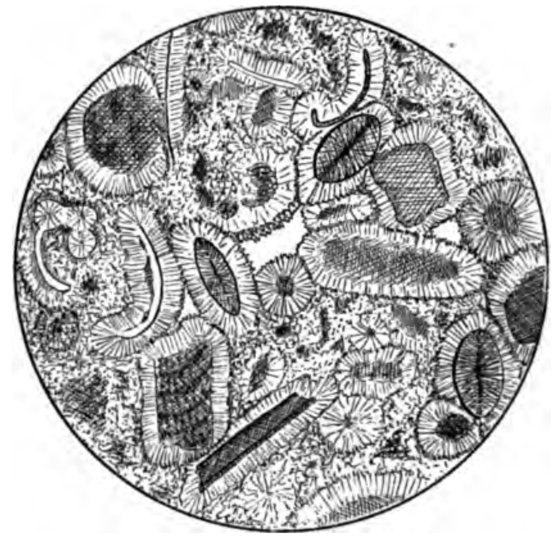


Fig. 28.—Main Boring. Core 36. Depth 30–40 feet. × 100.

Material intermediate in character between the coarser fragmental accumulations, which contain a large proportion of complete organisms, and the finest detritus. The fragments are cemented by fibrous encrusting calcite.

Fig. 29.—Main Boring. Core 111. Depth 103 feet. × 100.

Coral showing cavities containing secondary aragonite and calcite. Only one cavity contains calcite, which is of a different type to the fibrous encrusting calcite of figs. 26, 27, and 28, being much more perfectly crystallised. The other cavities contain aragonite deposited in continuity with the fibres of the coral.

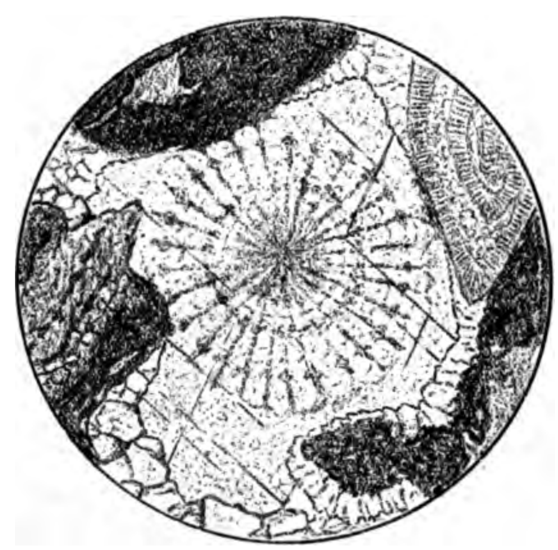


Fig. 30.—Main Boring. Core 183. Depth 210–220 feet. × 100.

The deposition of secondary calcite in crystalline continuity with that of the calcite organisms. Compare the urchin-spine and its investment with those in figs. 27 and 49.

b. The Crystallisation of the Fine Calcareous Detritus.

Deposition from solution is not the only process by which secondary calcite and aragonite are formed. Another change is observed as the cores are studied in descending order which also results in the formation of these minerals. This is not, however, one which affects the empty spaces of the rock, but those which contain finely divided calcareous detritus.

If a section, taken from the first two or three feet of the boring, be examined under the microscope, the contents of these cavities are seen to be quite fresh and unaltered; viewed by transmitted light they appear as dark, more or less opaque areas, owing to their finely comminuted condition (fig. 51). But in sections from deeper cores some of them are seen to become more or less transparent, owing to incipient crystallisation. The resulting clarification is at first local (fig. 32), showing that crystallisation commences at a number of points simultaneously, but by the extension of crystal growth from these starting points it eventually affects the whole cavity, which, with its crystallised contents, now closely resembles those which have been completely filled by deposition from solution (fig. 55). Indeed, in cores from some little way down it is not always easy to say by which of these two processes the crystalline contents of any particular cavity may have originated. Generally, however, the products of crystallisation of calcareous detritus are less transparent than those of deposition from solution, owing to the presence of minute particles which have remained uncrystallised; often, too, they may be distinguished by the presence of the unobliterated tube-like structures of boring organisms (fig. 31).

Fig. 31.—Main Boring. Core 92. Depth 70–80 feet. × 100.

Coral showing the crystallised contents of originally "mud"-filled cavities. The substance of the coral and the "mud" were traversed by boring organisms, whose tubes became subsequently filled with "mud," which has resisted crystallisation.

In the process of "mud" crystallisation, as in that of deposition from solution, the crystals formed, whether of calcite or of aragonite, sometimes exhibit an arrangement in continuity with the elements of the adjacent organisms. "Mud" lying within, or between, aragonite organisms, becomes converted into crystals of aragonite, each of which is continuous with an organic fibre (figs. 32, 35, 37, 54), while that occurring within or between calcite organisms is changed into crystals of calcite, often similarly disposed.

This phenomenon is seen only when the organisms possess a well-marked crystalline structure. When they do not, the product of crystallisation is usually an aggregate of granular calcite, the elements of which rarely show any marked relation to those of the contiguous organisms (figs. 33, 37).

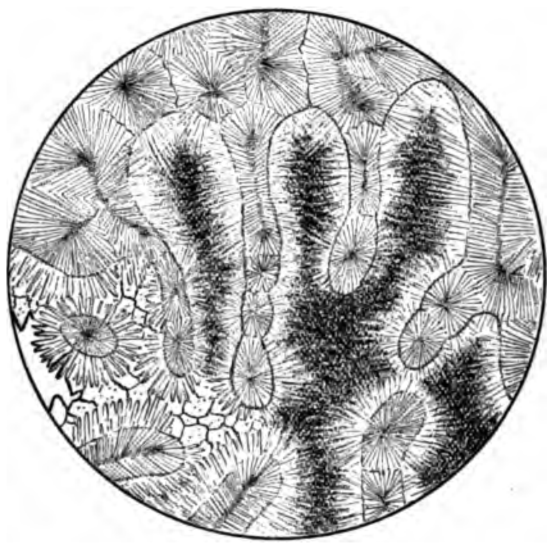


Fig. 32.—Main Boring. Core 105. Depth 90–100 feet. × 100.

Coral showing fine calcareous detritus in process of conversion into aragonite.

Fig. 33.—Main Boring. Core 141. Depth 160 feet. × 100.

Fine interstitial calcareous detritus in process of conversion into calcite. Some of the calcite has also been contributed by deposition from solution.

But although examples of perfectly crystallised "mud" are frequently seen in the sections, the actual proportion of it which undergoes complete clarification is quite small. Much of it is found, even in the deepest parts of the boring, almost as fresh in appearance as that which has been but recently deposited. In reality this has undergone crystallisation, but the granular elements into which it has been transformed are so exceedingly small that a casual inspection gives the impression that it is quite unchanged. The crystallisation of the fine detritus in this imperfect manner is one of the very first of the changes that take place in the rocks; its more perfect crystallisation must be regarded as somewhat exceptional.

Before dismissing the subject of the fine detrital matter, it will be convenient to mention here that it is not all contemporaneous—using that term in a broad sense—with the rocks in which it occurs. Some of it, on the contrary, is of subsequent origin, having made its way into the rocks after the lapse of a longer or shorter period during which the cavities had become lined with crystals deposited from solution (figs. 34, 46). Moreover, the cavities which arise in the rocks by the removal of organisms in solution are frequently seen to contain fine calcareous material, which must obviously be of comparatively late introduction into the mass (fig. 65). This,

which may be called secondary "mud," is usually easily distinguished from the truly contemporaneous (primary) "mud" by its mode of occurrence and by certain peculiarities in its texture (fig. 34).

The conversion of the fine calcareous detritus into secondary aragonite and calcite, together with the deposition of secondary aragonite and calcite, which has already been described, cause the rocks to become gradually more and more crystalline in character as the boring is descended.

Fig. 34. Main Boring. Core 204. Depth 373–378 feet. × 100.

"Coral-reef sand" with interstitial spaces containing primary "mud," crystalline calcite, and secondary "mud." The primary "mud"—to the right of the central organism—is seen to come into direct contact with the organisms; but the secondary "mud" is separated from them by a layer of deposited crystals.

(c) *The Disappearance of Aragonite.*

From the surface down to a depth of about 100 feet the cores are largely composed of well-preserved aragonite, but near this depth signs begin to appear of changes, which ultimately lead to the complete disappearance of this mineral. The processes by which this result is brought about are two, the conversion of aragonite into calcite, and the removal of aragonite by solution. The former process will be considered first.

The earliest sign of this approaching change is the cessation of the deposition of secondary aragonite in cavities already partly filled with it, and the deposition of calcite instead (figs. 35, 36, 56). The calcite is seen to occupy the more central portion of the cavities, and rests upon and encloses the apices of the aragonite crystals in such a manner as to leave no doubt that it is a product of deposition and not of the conversion of pre-existing aragonite. The direct deposition of calcite upon the secondary aragonite, in this manner, points to the supervention of conditions which were no longer suitable for the precipitation of calcium carbonate as aragonite; such as continued to be thrown down being deposited as calcite. This condition is immediately followed by the breaking down of the secondary aragonite, and its recrystallisation as calcite, with the result that the cavities now contain the latter mineral only. But for a time the primary aragonite of the organisms withstands this conversion. Eventually, however, it also is attacked, and passes over into calcite.

The recrystallisation of the aragonite organisms results in the complete loss of that organic texture which was originally characteristic of them, only the bolder features of form and structure being preserved, and it is by these alone that they can be identified.

This loss of organic texture and conversion into calcite is a gradual process, the various stages of which may be followed particularly well in thin sections of the corals. The first indication of loss of organic texture in the coral is the disappearance of the "dark line," a series of comparatively dense and opaque centres from which the component fibres of the coral substance radiate. In a perfectly fresh coral these form a very conspicuous dark moniliform line, occupying the middle of the coral wall, but, as lower and lower cores are examined, this line becomes less and less distinct and presently disappears. The next stage is the gradual obliteration of the fibres

Fig. 35.—Main Boring. Core 105. Depth 90–100 feet. × 100.

Coral showing cavities completely filled with secondary crystals deposited from solution, and others containing calcareous detritus in process of crystallisation. Of the former cavities, two contain aragonite only, the third, calcite in addition.

Fig. 36.—Main Boring. Core 111. Depth 103 feet. × 200.

Coral surrounded by a fringe of secondary aragonite, which is in turn invested by a more or less continuous layer of calcite crystals. The prismatic crystals of aragonite show no signs of conversion into calcite. The calcite outside them represents the latest product of deposition from solution: the formation of aragonite has been superseded by that of calcite.

themselves. Yet later, the substance of the coral is seen to be broken up by a number of sinuous lines into a granular mosaic; but, for a while, both the granular structure and something of the fibrous character may be discerned (figs. 37, 57). Finally all traces of the fibres disappear, and the mass becomes an aggregate of irregularly rounded and mutually interfering grains of calcite (figs. 37, 38, 58). The secondary aragonite of the cavities has already undergone a similar change, so that now the whole mass, coral substance and crystal-filled cavities alike, is composed of granular calcite. The only respect in which the granular aggregate, resulting from the conversion of the coral substance into calcite, may be distinguished from that

resulting from the recrystallisation of the aragonite of the cavities, is that the former is less transparent than the latter, and still retains something of the yellowish or brownish tint, which is so pronounced in sections of fresh coral, whereas the latter is perfectly colourless (figs. 38, 57, 58). Ultimately, though at a lower level, even this difference disappears, and it is then often quite impossible to say of a mass that is evidently altered coral, which part is altered coral substance, and which the crystallised contents of the cavities.

Fortunately a very considerable proportion of the organisms which have undergone

Fig. 37.—Main Boring. Core 145. Depth 170–180 feet. × 100.

Coral showing various stages in the conversion of aragonite into calcite. The least altered part of the coral is a fragment occurring embedded in dense "mud" in the left lower quadrant of the field; the most altered occurs in the right lower quadrant, where it has been completely converted into granular calcite. The calcite of the cavities is clearer than that of the coral substance. Two of the cavities contain "mud," which has in one case been partially converted into crystalline aragonite, and in the other into crystalline calcite.

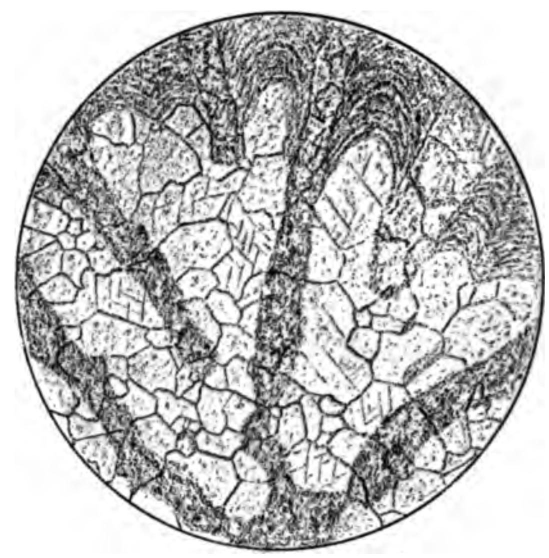


Fig. 38.—Main Boring. Core 305. Depth 603–612 feet. × 100.

Coral completely converted into calcite. The calcite of the cavities is water-clear, that of the coral substance somewhat opaque.

recrystallisation, whether they be corals or not, are seen in section to be bounded peripherally by a narrow dark band or line, which defines their original form and thus causes their general outline to be still discernible (figs. 62, 63, 64, 68, 69). This dark line probably results from the presence, upon the surface of the original organisms and fragments, of a thin film of finely-divided detritus, which has not crystallised, or has

done so only imperfectly.* It is of great service in the microscopic examination of the rocks of coral reefs in which crystallisation of the organisms has occurred. But for its presence the identification of the original constitution of many such rocks would be quite impossible; but revealing, as it does, the shape of the various constituent bodies of which the mass was, in the first place, composed, this becomes in many cases a matter of no great difficulty. It is obviously of greatest use in those rocks which have undergone the most extreme crystallisation, and in which, as a consequence, the primary characters have been most completely obscured.

The second of the two processes by which aragonite disappears from the boring, namely, its disintegration and removal in solution, is one that produces results which are not only appreciable under the microscope, but are also obvious in the cores when examined with the naked eye. It is expressed first by the appearance, in the substance of the aragonite organisms, of numerous small and irregular holes, which impart a porous or spongy character to it (fig. 59). Later, these holes are seen to become gradually larger, and eventually an empty cavity, retaining merely the form of the original organism, alone remains. These empty spaces render the cores highly cavernous, and light in weight; many of them, which were formerly occupied by coral, show an interesting phenomenon which will be briefly described, since it explains the peculiar mode of preservation of the corals in certain parts of the boring. If a section be cut of a rock containing a mass of coral more or less surrounded by fine calcareous detritus, the peripheral cavities of the coral, which are in communication with the exterior, are seen to be "mud" filled, while those which, because of their more internal position, are inaccessible to suspended matter, are either empty, or contain crystals of secondary aragonite deposited from solution. When such a mass is attacked by solvent action, the whole of the aragonite, both primary and secondary, is dissolved out, but the "mud" of the peripheral cavities, consisting, as it does, of calcite, remains unaffected. The result is that an empty space is produced, from the walls of which casts in "mud" project inwards for a certain distance, forming reversed presentations of the form of the external parts of the coral (fig. 60). This, which may be spoken of as the phenomenon of reversal, is of very common occurrence in the boring, and especially in its lowest portions.

It has already been stated that the disappearance of aragonite begins at about 100 feet down in the boring. As the cores from below this depth are examined in descending order, it is seen to proceed more and more rapidly. At a depth of 150 feet or so practically all aragonite is gone, only occasional patches of the mineral in an advanced state of recrystallisation, or of disintegration, being encountered at greater depths, and none, up to the present, having been detected at depths exceeding 220 feet.

Below this depth, therefore, and so long as the rocks consist essentially of calcium

* SKEATS: 'Bull. Mus. Comp. Zool. (Harvard),' vol. 42, June, 1903, pp. 109, 110.

carbonate, as they do down to 637 feet, calcite is the only mineral which enters into their composition. Of that part of the boring which lies between these two depths (220 feet and 637 feet) a comparatively small proportion only consists of solid cores; the greater portion is either entirely unrepresented or is represented only by loose and incoherent material, which resembles unconsolidated "coral-reef sand." Such cores as do occur consist in great measure of calcite organisms, with only very occasional remains of aragonite organisms, and these always recrystallised into calcite, and usually showing signs of having been to some extent dissolved in the process of transformation. Large masses of dense and solid coral rock, such as occur so abundantly in the highest parts of the boring, are here practically non-existent. As regards the loose fragmental material, a careful examination furnishes the following facts. The grains are irregular in shape and of no uniform size; they consist, for the most part, of calcite organisms, or broken portions of such; aragonite organisms in their original mineralogical state do not occur, those which are found being mineralised into calcite. The particles are often surrounded more or less completely by a ragged fringe of calcite crystals, from the presence of which it may be inferred that they were at one time consolidated by a crystalline cement. No rounding of the grains is apparent; on the contrary, the broken crystals which so frequently occur upon them are often delicate and sharply pointed, and, moreover, cleavage fragments of calcite, with sharp unworn edges, are quite common, suggesting the action of some violent disruptive force.

These facts point to the conclusion that the rocks of these middle parts of the boring have suffered much by that solution of aragonite which is seen to set in at a depth of about 100 feet, and to proceed so rapidly with descent. Originally, no doubt, these rocks consisted, as those above them still do, of mixtures of calcite and aragonite in various proportions, but the latter mineral has entirely disappeared from them, a certain small proportion having been changed *in situ* into calcite, but by far the greater proportion having been carried away in solution. Such of them as were originall composed mainly of calcite have been but little affected by this solvent action, a are still sufficiently coherent to yield solid cores. But those which containe greater portion of aragonite have been rendered so porous by the removal of mineral, that the operations of boring have reduced them to a fragmental and inc condition, and in this state the materials of which they were composed h brought to the surface. The amount of solid rock which has been rem manner is, in these parts of the boring, far in excess of that whic the insoluble calcite residue.

(3) The Mineralogical Characters of the Rocks from TO 1114 FEET.

ks included between these limits are, for the most part nesium carbonate, and composed of th

magnesium carbonate. The rise in the proportion of this constituent is therefore very sudden; but it is probably not quite so abrupt as these facts would imply, for number of small fragments, the precise position of which, in the boring, is uncertain but which are known to belong hereabouts, and most likely come from between the two cores in question, have given intermediate values. Sections of these fragments show some to consist of calcite only, others of calcite and dolomite. One of the former kind was analysed by Dr. SKEATS, and gave 3·82 per cent. of magnesium carbonate, while of three of the latter kind, two gave 11·67 per cent. and 16·21 per cent. respectively, and the third 29·72 per cent.

The cores following below that in which dolomite is first seen show a gradual increase in the proportion of magnesium carbonate, until a maximum of 40 per cent. or thereabouts is reached, at a depth of 650 feet.

When sections cut from a number of these cores are examined in descending order, this increase is seen to be represented by the gradual growth and extension of the areas composed of dolomite at the expense of those of calcite. So long as the proportion of magnesium carbonate falls short of its maximum, areas of unaffected calcite may still be discovered, but, as the maximum is approached, such areas become smaller and less numerous, and by the time it has been actually attained they have all disappeared, calcite having everywhere given place to dolomite. It is interesting to trace the various stages by which this progressive dolomitisation is effected. Sections taken from the depth of 637 feet consist entirely of calcite, partly of primary, partly of secondary origin. The rock here is very porous, and the interstices are lined with acute scalenohedral crystals of calcite, which are often disposed in continuity with the structural elements of the organisms by which the cavities are lined (fig. 39). In sections taken only a foot lower down dolomite is seen to be present as well as the primary and secondary calcite. The rock is less porous than that immediately above, the cavities being now in part occupied by crystals of dolomite which rest upon and enclose the projecting apices of the scalenohedra of secondary calcite (fig. 40; Plate F, fig. 3). If these dolomite crystals could be removed, the remainder would be essentially identical with the rock at 637 feet. It would appear, therefore, that the dolomite is, in part at least, an addition to the mass by direct deposition, and not always a substitution product for pre-existing calcite. As sections from successively deeper cores are examined, the lining of scalenohedral calcite, which intervenes between the unaltered organisms and the subsequently deposited dolomite, is seen to disappear by conversion into dolomite, which latter, by a process of inward invasion, ultimately comes into direct contact with the organisms themselves (Plate F, fig. 3), and the sites of aragonite organisms, which in the cores above are composed of secondary calcite, are also rapidly usurped by dolomite. At this stage the rock consists only of primary calcite and of dolomite, all secondary calcite having been changed into dolomite. It appears, therefore, that the secondary calcite of these rocks is more readily converted into dolomite than the primary calcite.

This fact is of interest, as an analogous difference in permanence may be observed in those parts of the boring where aragonite is altering to calcite; it is the secondary aragonite which first undergoes the paramorphic change, the substance of the corals and other aragonite organisms preserving its integrity after the secondary aragonite of the cavities has been converted into calcite.

As still deeper cores are studied, the process of invasion by which the secondary calcite has been converted into dolomite is seen to attack the primary calcite of the organisms, with the ultimate result that they also become completely dolomitised. This change may or may not involve their re-crystallisation. When it does, the

Fig. 41.—Main Boring. Core 342. Depth 660 feet. × 10.

Showing the characters of the "soft dolomite," as seen with low powers of the microscope. In many cases the solid substance of the organisms has been entirely dissolved out, only the cells and tubules, filled with dolomitised "mud," remaining. In others a certain proportion of the organic substance has withstood the solvent action, but has been converted into dolomite.

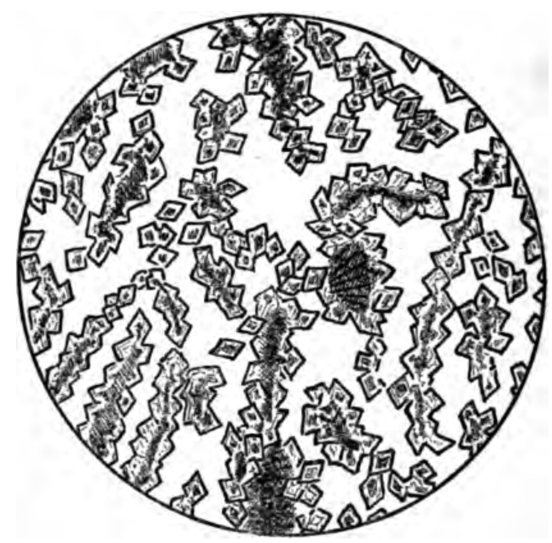


Fig. 42.—Main Boring. Core 366. Depth 698 feet. × 200.

A well-crystallised portion of the "soft dolomite," highly magnified. The mass is mainly composed of groups and strings of minute rhombohedra of dolomite, which define in a general way the outlines and major structural features of the organisms which were the original constituents of the rock. Here and there, in the midst of the larger groups of crystals, fragments of uneffaced organisms may still be recognised.

result is occasionally the almost entire obliteration of them, but much more often it is the destruction of their minor features of texture and structure only (fig. 43), their major features of structure and form continuing to be more or less evident. When, on the other hand, dolomitisation does not involve recrystallisation of the organisms, as is occasionally the case, their detailed structure may be preserved, and sometimes in a remarkably perfect manner.

The increase of dolomite, at the expense of calcite, continues until none of the latter mineral remains. At the depth of 650 feet, or thereabouts, practically all

calcite has disappeared, and thence, to the depth of 820 feet, with the rare exception of an incompletely converted organism, nothing but dolomite can be identified in the cores. Throughout the whole of this 170 feet the composition of the rocks is remarkably uniform; the proportion of magnesium carbonate is about 40 per cent., sometimes a little less, occasionally a little more, but in no part of the boring, either here or elsewhere, does it exceed 43 per cent.

The proportion of magnesium carbonate in pure dolomite is 45·65 per cent. If 40 per cent. be taken as the average amount of magnesium carbonate in these most highly dolomitic rocks of the boring, and that be considered to be combined with calcium carbonate in the proportions represented by the formula $CaCO_3.MgCO_3$, then they must contain an excess of uncombined and uncrystallised calcium carbonate amounting to 13 per cent. or so. This may be included in the dolomite as an invisible impurity, but possibly it is this material which, in the condition of minute particles, renders a large proportion of the dolomite crystals more or less opaque, and often causes that zoned appearance which is so characteristic of dolomite in sedimentary rocks (figs. 42, 48).

The dolomites, which for 170 feet in this part of the boring maintain this peculiar constancy in chemical and mineralogical composition, are by no means uniform in their lithological character. Normally, the dolomites of the boring are dense and compact rocks, and a certain proportion of those of this 170 feet are of this nature, but for the 80 feet included between the depths of 660 feet and 740 feet they are of a totally different character, being so soft and friable as to crumble readily under the finger nail, and so porous as to feel, in the hand, scarcely heavier than pumice. The reason of these peculiar characters becomes evident under the microscope. When the rocks below 650 feet are examined in descending order, it is observed that many of the organisms show signs of corrosion by solution. The number of the organisms so affected increases with the depth, and also the proportionate part of each organism removed by solution; and at the depth of 660 feet the organisms present the appearance shown in fig. 41. Solution has here removed much of their original substance, and especially certain parts which seem to be more readily dissolved than the rest, with the result that they are now little more than sponge-like skeletons of what they were originally. The undissolved parts are composed of dolomite, and each organism is invested by a very thin layer of tiny dolomite crystals. These are often very perfect in form, appearing in sections as minute isolated or nearly isolated rhombohedra. The majority of them contain a central zone or nucleus of the same form as the crystal itself, composed of a white opaque or semi-opaque material (fig. 42). The outer part of the crystal, which is transparent, is probably composed of pure or nearly pure dolomite. The central kernel, however, probably owes its opacity to the presence of calcareous impurity, which represents the excess of calcium carbonate which the rocks contain over and above that present in pure dolomite. As the middle of this 80 feet of soft dolomite is approached, signs of solution

become more evident, and of such material as remains a larger proportion consists of the tiny zoned rhombohedra, and a smaller proportion of recognisable organisms (fig. 42); but with the exception of these variations in degree of solution and crystallisation, the rocks remain of the same essential nature through the whole of the interval between 660 and 740 feet. At about the latter level the cores begin to get heavier and harder once more, and within a very few feet they assume a dense and solid character. This change is denoted in thin sections by the gradual, though rapid disappearance of those evidences of solution which are so abundant in the rocks above.

Between the base of this soft dolomite and the point, another 80 feet lower down, at which the proportion of magnesium carbonate begins once more to lessen, the cores remain of the hard, dense and compact type (fig. 43), and such sections as have been cut from them reveal no important recurrence of those signs of excessive solution which are so distinctive of the soft dolomite above; but the rocks exhibit all the various types of dolomitisation of the organisms which have already been described.

Fig. 43.—Main Boring. Core 51A. Depth about 760 feet. × 30.

Dolomitised "coral-reef sand." The calcite organisms, though dolomitised, show little sign of crystallisation; the aragonite organisms, on the contrary, are almost completely recrystallised, and have consequently lost all their more delicate original characters. The granular cement probably represents, in large part, crystallised "mud," comparatively unaltered patches of which are seen here and there in the section. The dark line defining the original boundaries of the recrystallised organisms is well seen.

It may be mentioned here, that the phenomenon of reversal, already described on p. 403, is very characteristic of these lower parts of the boring. It is particularly well displayed by the corals, which are often preserved in the form of casts, the solid substance of the coral having been removed in solution, while the "mud" of the cavities has remained undissolved. The coral substance has not always been dissolved out, however; sometimes it has been converted into secondary calcite, and this in its turn, at the horizons of complete dolomitisation, has been converted into dolomite. In such cases the corals are not preserved in the form of casts, but have simply undergone one or more changes of mineralisation. The mud of the cavities is usually dolomitised, but occasionally it still consists of calcite.

b. The Occurrence of Fibrous Deposits in the Cavities.

At the depth of about 815 feet the fibrous encrusting deposit which has already been stated to occur in the lower parts of the boring makes its appearance.

It is at first very thin, and constitutes only a minute proportion of the mass ; but traced downwards it increases rapidly in thickness and soon becomes an abundant and conspicuous element in the rocks (Plate F, figs. 4, 5, 6). With occasional interruptions and many variations in its detailed constitution, it continues to the bottom of the boring.

Mineralogically it is at first composed entirely of calcite. At greater depths it sometimes consists of calcite throughout (Plate F, figs. 4, 5), sometimes of regularly alternating layers of calcite and dolomite—the dolomite layers being thin in comparison with those of calcite, and destitute of the fibrous structure (figs. 44, 48 ; Plate F, fig. 6) — and sometimes of dolomite throughout (figs. 45, 49). Occasionally it may be uniformly clear and transparent, but usually it exhibits a very marked concentric structure produced by bands—from two or three to as many as fourteen or fifteen in number —of different degrees of transparency, which impart to it a markedly agate-like appearance. Associated with it, in the cavities in which it occurs, are numerous floors of "mud" (fig. 46), and there is repeated evidence that the darker layers of the deposit owe their comparative opacity to the inclusion of this finely divided silt within their substance. The deposit appears to have been formed in waters which were alternately clear and turbid with suspended matter, which settling slowly down accumulated in the irregularities of the cavity floors. Its occurrence as the innermost lining of the cavities proves it to be the latest addition to the rocks, by deposition from solution ; its introduction, moreover, did not take place until after solvent action had affected many of the corals and other aragonite organisms, for it is frequently found lining or filling spaces which were formerly occupied by these. In this respect it differs from the similar fibrous deposits seen in the first few feet of the boring, where the organisms of aragonite are as fresh and solid as those of calcite (Plate F, figs. 1 and 2). Moreover, there can be little doubt that, in many cases, the rocks in which it

Fig. 44.—Main Boring. Core 205A. Depth 830 feet. × 100.

Cavity, in dolomitised rock, containing banded encrusting deposit consisting of three layers, the first and third of which are of calcite, the second of dolomite. The dolomite layer may represent part of the original deposit converted into dolomite, or, as seems more probable, it may have been deposited directly as such. The encrusting material, the introduction of which was apparently subsequent to the dolomitisation of the rock, is separated from the boundaries of the original organisms by a layer of well-formed water-clear dolomite crystals (see also fig. 48 and Plate F, fig. 6).

occurs were at least partially, if not completely, dolomitised before its deposition in their cavities.

Below 820 feet and above 875 feet the rocks are dolomitic limestones containing a variable amount of recognisable calcite. At the upper of these two limits they contain 39 per cent. of magnesium carbonate, and the proportion of calcite is very small indeed; at the lower limit they contain 40·25 per cent. of magnesium carbonate, and there is no calcite at all, but as a descent is made from the upper limit, or an ascent from the lower, the relative amount of calcite rapidly increases, and for a considerable distance above and below a point situate mid-way between them, calcite constitutes not less than half the mass. Such analyses as have been made from the cores of this part of the boring show a maximum of calcite at 826 feet, where the proportion of magnesium carbonate is less than 5 per cent. (4·83). If it be assumed that this amount of magnesium carbonate is combined with calcium carbonate to form dolomite, and that all the rest of the calcium carbonate exists as visible calcite, then approximately nine-tenths of the mass must be composed of calcite and only one-tenth of dolomite, a conclusion which is quite in accord with what is observed in stained sections.

Starting from this point, at which so large a proportion of the mass consists of calcite, and working both upwards and downwards towards the condition of complete dolomitisation which exists above and below, it is interesting to note just the same series of changes as is to be observed in passing from the limestones at 637 feet into the dolomites below. In the rocks which contain the smallest proportion of dolomite, and which, except for the presence of the fibrous encrusting deposit, may be compared with those at 638 feet, the calcite of the mass comprises the primary calcite of the unaltered organisms, the secondary calcite of the organisms that were originally composed of aragonite, and the secondary calcite deposited from solution, which last is of two kinds—an earlier-formed deposit of acute scalenohedral crystals investing the organisms, and the later-formed fibrous encrusting deposit. The dolomite of the mass consists in the main of transparent crystals—there is also some dolomitised "mud"—which cover up and enclose the scalenohedra of calcite or invest the calcitised aragonite organisms (Plate F, fig. 4) in such a manner as to leave little doubt that they are the direct product of deposition from solution. They are themselves covered up by the fibrous encrusting deposit of calcite.

A little higher up and a little lower down much of the secondary calcite gives place to dolomite, but the primary calcite of the organisms still remains unchanged, and so, in great measure, does the fibrous encrusting deposit.

Finally, as the distance from the starting point is gradually increased, and the horizons of complete dolomitisation, above and below, are more and more nearly approached, even the calcite organisms are attacked and pass over into dolomite; the fibrous deposit too, when followed downwards, is seen to be dolomitised; traced

upwards it gradually diminishes in amount and finally disappears, so that at 820 feet on the one hand and 875 feet on the other, practically all calcite has disappeared.

Although the stages of this progressive dolomitisation, when studied in detail, are neither quite so simple nor quite so regular as here described, owing to local disturbing influences, it is believed that the general sequence of the changes here indicated is substantially correct.

From 875 to 1050 feet the rocks are again composed almost exclusively of dolomite,

Fig. 45.—Main Boring. Core 389A. Depth 926–936 feet. × 30.

Dolomitised "coral-reef sand" cemented by fibrous encrusting material. The fibrous deposit is in places coated with well-defined water-clear crystals of dolomite. The rock, except for changes which have accompanied dolomitisation, is identical in character with that represented in fig. 27.

Fig. 46.—Main Boring. Core 503A. Depth 987–991 feet. × 100.

Dolomitised coral, with an irregular cavity containing dense homogeneous detritus and fibrous encrusting calcite. The fibrous deposit is the only calcite in the section. Neither the "mud" nor the fibrous material comes into direct contact with the coral. Each is separated from it by a layer of clear dolomite crystals.

visible calcite in the form of undolomitised structures being of rare occurrence. They contain, however, the same excess of uncombined calcium carbonate as the rocks occurring between 650 and 820 feet, the proportion of magnesium carbonate being approximately 40 per cent.

The most variable constituent in them is the fibrous encrusting deposit. This is sometimes entirely absent, sometimes scarce, and sometimes abundant; it displays no constancy in its mineralogical composition, consisting most commonly of dolomite, but often of alternating layers of dolomite and calcite. Finely divided dolomitised detritus is common, and forms conspicuous floors to the cavities (fig. 46). At several

horizons the rocks show signs, not only under the microscope, but also with the naked eye, of that solution which has produced such striking results in the soft dolomite occurring higher up in the boring (fig. 45). In no case, however, are the effects of solution here so marked as at that horizon, nor have the rocks affected so great a vertical extent. That solvent action did not come into operation until after the deposition of the fibrous encrusting material is proved by the fact that just as parts of the organisms have been dissolved away, so, occasionally, have the more soluble layers of this material itself been removed by solution—layers which are now represented by a series of roughly concentric or parallel vacuities.

The other characters of the dolomites at this depth, the state of preservation of the various organisms, their modes of mineralisation and so forth, are in all essentials identical with those of the rocks of the same composition which occur higher up in the boring. Indeed, the lower dolomites differ from those above only in the presence of the fibrous encrusting material and the greater abundance of detrital mud.

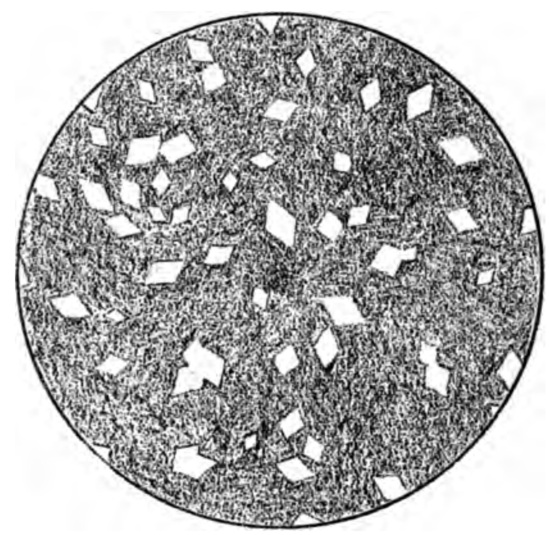


Fig. 47.—Main Boring. Core 618A. Depth 1060–1066 feet. × 100.

Dolomitised "mud" containing well-formed dolomite crystals.

Between 1050 and 1070 feet dolomitic limestones occur once more. At the former depth, calcite, which in the dolomites immediately above is of very rare occurrence and constitutes, at most, but an insignificant proportion of the mass, begins to increase in quantity. This increase continues until the depth of 1060 feet, or thereabouts, is reached, from which point a corresponding decrease ensues, with the result that, finally, at or about 1070 feet, dolomite is once more established in overwhelming preponderance, and so continues with little variation to the bottom of the boring.

Starting from the level (1060 feet) at which the proportion of calcite is greatest—rather more than two-fifths of the mass—and working both upwards and downwards, the changes which present themselves are the same in kind and order as were observed in the dolomitic limestones occurring between the depths of 820 and 875 feet. At first the calcite comprises not only the majority of the organisms which are primarily composed of it, but also a certain proportion of unaltered secondary calcite, whether it be that which in the form of scalenohedral crystals invests the calcite organisms, or that which represents the products of the paramorphism of the corals and other aragonite organisms, or that which as the fibrous deposit lines or fills the cavities of the mass. The dolomite consists of

crystals which may have been in part deposited directly as such, or may represent secondary calcite dolomitised; a portion of the fibrous encrusting material also is generally composed of dolomite; and when finely divided detritus occurs, it, too, is dolomitic almost without exception. Higher up and lower down the secondary calcite more or less completely disappears, being gradually replaced by dolomite; and, lastly, the calcite organisms are affected; some alter earlier than others, but practically all have suffered conversion into dolomite when the upper limit of 1050 feet,

Fig. 48.—Main Boring. Core 671A. Depth 1090 feet. × 200.

Partially dolomitic encrusting deposit occupying a cavity in dolomitised coral. The recrystallised coral substance is separated from the fibrous material by a layer of comparatively clear dolomite crystals. Of the five layers of the encrusting deposit the first, third, and fifth are of calcite, the second and fourth of dolomite.

Fig. 49.—Main Boring. Core 709A. Depth 1114 feet. × 35.

Section of the deepest core. The organisms are bound together by a cement of three layers. The first layer is fibrous and somewhat opaque with included "mud"; the second layer is a little more definitely crystallised and is less opaque with included matter; the third layer is well crystallised and water-clear. Organisms and cement alike are composed of dolomite.

or the lower limit of 1070 feet, is reached. None of the rocks included in this 20 feet show signs of solution.

c. *The Characters of the Lowest Rocks reached in the Borings.*

From 1070 feet to the bottom of the boring (1114 feet) the rocks consist once more of dolomite, to the complete or almost complete exclusion of visible and recognisable calcite. What little calcite they do occasionally contain consists, for the most part, of undolomitised or incompletely dolomitised calcite organisms; occasionally also the

fibrous encrusting deposit is partly composed of calcite, but by far the greater proportion of this material is of dolomite throughout. From about 1100 feet downwards the rocks show somewhat marked signs of solution.

The lowest core of the boring is composed of consolidated dolomitised "coral-reef sand." It is made up of various small organisms, or fragments of organisms, which are bound together by well-marked fibrous encrusting material, which more than usually resembles that occurring near the top of the boring, in that it comes into actual contact with the original bodies of the rock, and is not separated from them by an intervening layer of dolomite crystals.

A Series of Diagrammatic Figures illustrating some of the numerous Conditions of Preservation and Types of Mineralisation exhibited by the Corals in different Parts of the Boring.

(For the purpose of making clear the relations which exist between the various conditions illustrated, the same coral form has been reproduced in all the figures. In this respect, therefore, they are diagrammatic, but in other respects they represent in a fairly accurate manner what is actually seen under the microscope.)

Fig. 50.—Fresh coral with empty cavities. The coral-substance composed of primary aragonite.

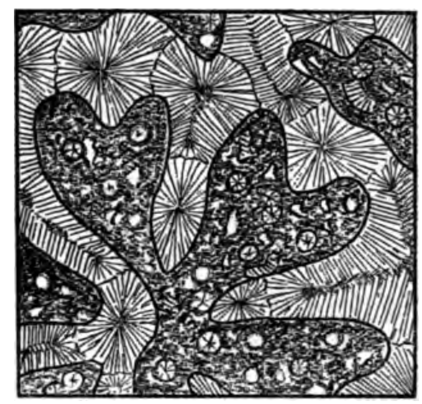


Fig 51.—Coral-substance aragonite; cavities filled with fine calcareous detritus.

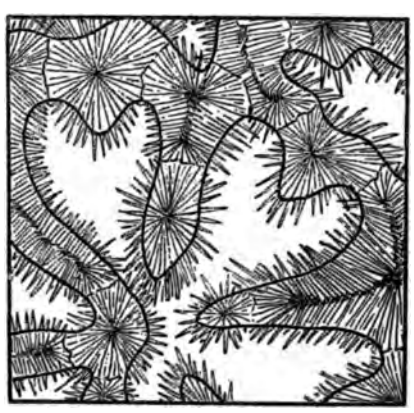


Fig. 52.—Coral-substance aragonite; cavities partly filled with secondary aragonite, deposited from solution; crystals continuations of the coral fibres.

Fig. 53.—Coral-substance aragonite; cavities partly filled with fibrous encrusting deposit of secondary calcite; crystals not continuations of the coral fibres.

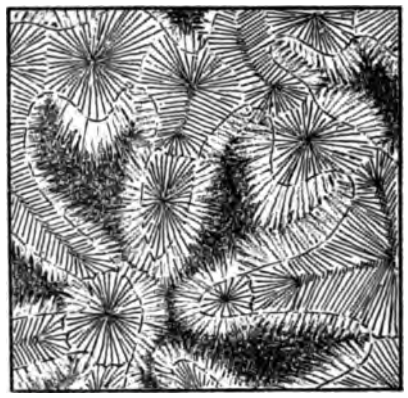


Fig. 54.—Coral-substance aragonite; cavities containing fine calcareous detritus in process of conversion into secondary aragonite.

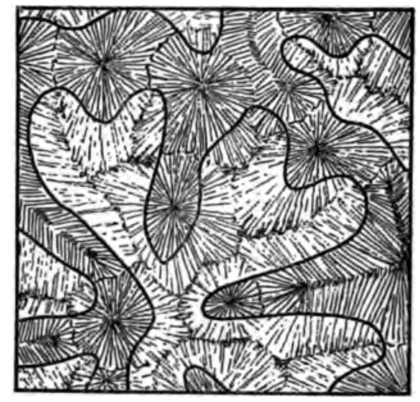


Fig. 55.—Coral-substance aragonite; cavities completely filled with secondary aragonite.

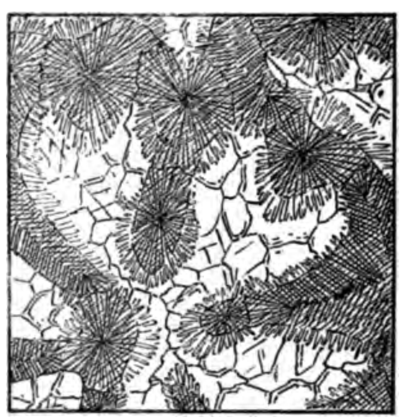


Fig. 56.—Coral-substance aragonite; cavities containing secondary calcite deposited upon secondary aragonite.

Fig. 57.—Coral substance passing from aragonite to secondary calcite; cavities filled with secondary calcite.

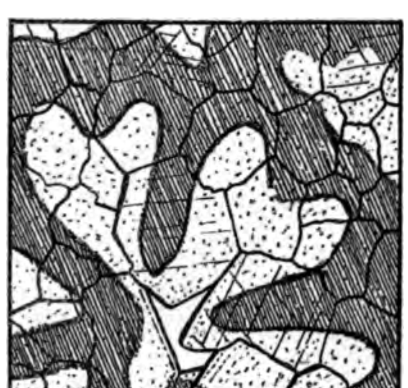


Fig. 58.—Coral substance and contents of cavities, both secondary calcite.

Fig. 59.—Coral-substance aragonite, in process of removal by solution; cavities filled with finely-divided calcareous detritus.

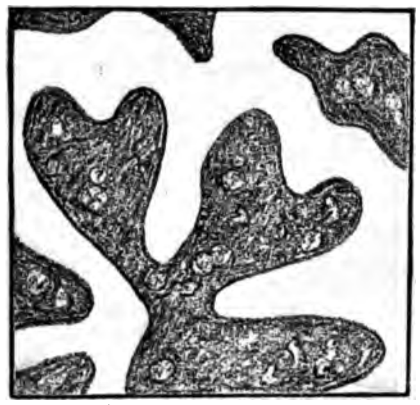


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the re-crystallised coral by a well-marked "dirt line."

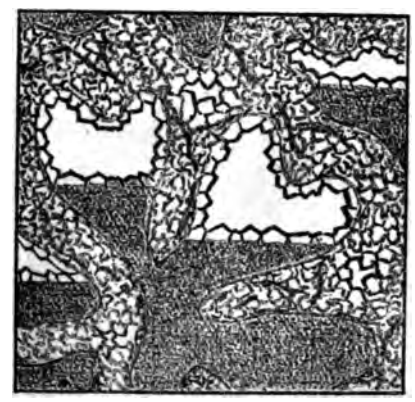


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

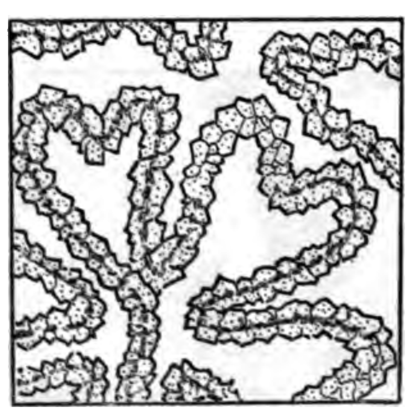


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

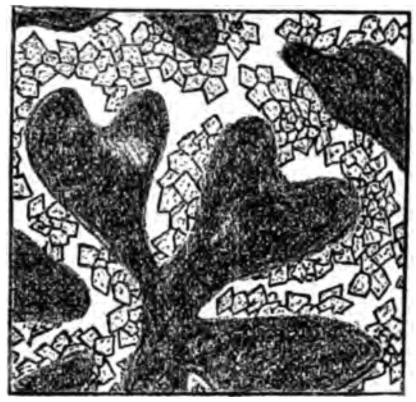


Fig. 66.—Coral substance replaced by porous mass of dolomite crystals; cavities filled with fine calcareous detritus dolomitised.

Fig. 67.—Coral substance converted into granular calcite; cavities containing water-clear calcite in some cases, and in others first a layer of transparent dolomite crystals, and then fibrous encrusting material consisting of alternating layers of calcite and dolomite.

Fig. 68.—Originally coral with cavities partly filled with fine calcareous detritus; coral substance removed by solution; cavities so formed, and those incompletely filled with calcareous detritus, lined with crystals of calcite, deposited from solution, the whole then dolomitised, and, lastly, fibrous encrusting calcite, deposited in certain of the empty spaces.

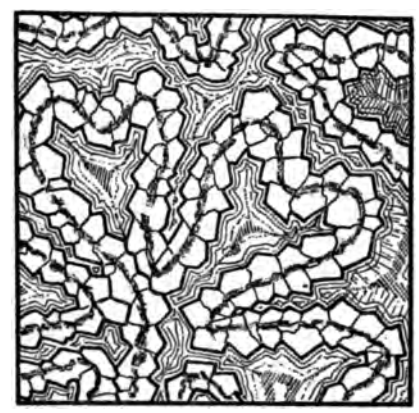


Fig. 69.—Originally coral with empty spaces; coral substance removed by solution; cavities so formed and the original cavities of the coral lined with calcite crystals; these converted into dolomite; and lastly remaining cavities filled with fibrous encrusting deposit of calcite.

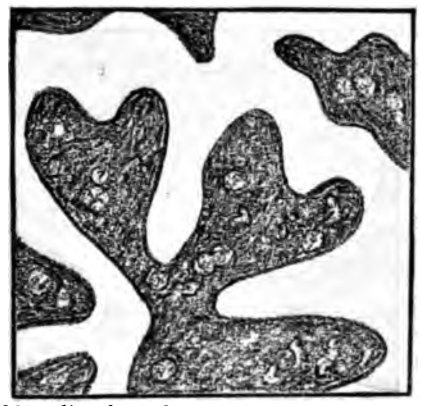


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the recrystallised coral by a well-marked "dirt line."

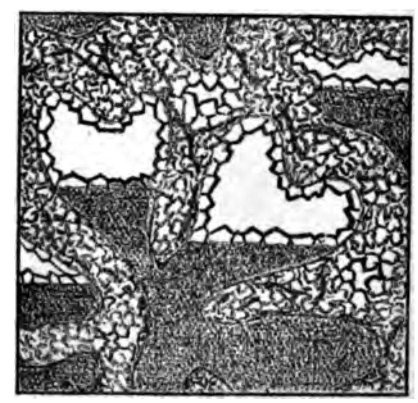


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

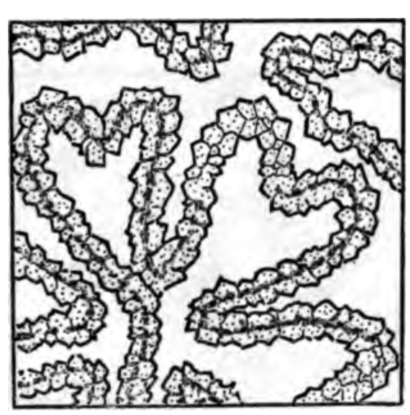


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

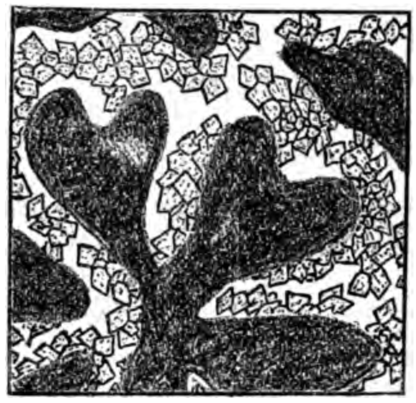


Fig. 66.—Coral substance replaced by porous mass of dolomite crystals; cavities filled with fine calcareous detritus dolomitised.

Fig. 67.—Coral substance converted into granular calcite; cavities containing water-clear calcite in some cases, and in others first a layer of transparent dolomite crystals, and then fibrous encrusting material consisting of alternating layers of calcite and dolomite.

Fig. 68.—Originally coral with cavities partly filled with fine calcareous detritus; coral substance removed by solution; cavities so formed, and those incompletely filled with calcareous detritus, lined with crystals of calcite, deposited from solution, the whole then dolomitised, and, lastly, fibrous encrusting calcite, deposited in certain of the empty spaces.

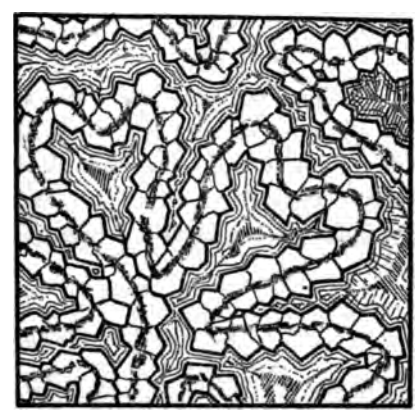


Fig. 69.—Originally coral with empty spaces; coral substance removed by solution; cavities so formed and the original cavities of the coral lined with calcite crystals; these converted into dolomite; and lastly remaining cavities filled with fibrous encrusting deposit of calcite.

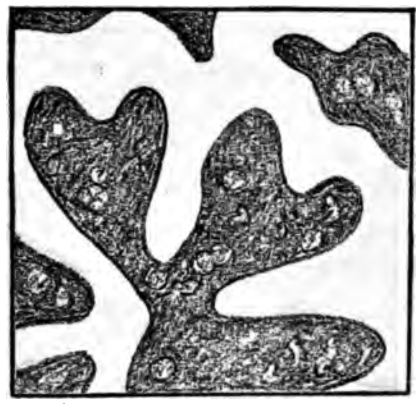


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the recrystallised coral by a well-marked "dirt line."

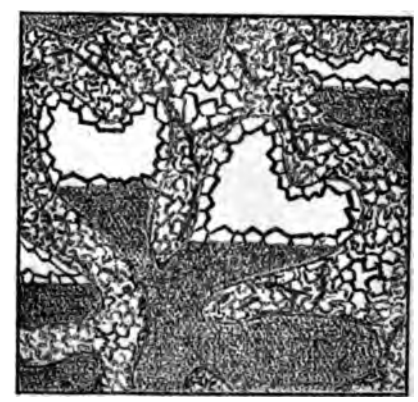


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

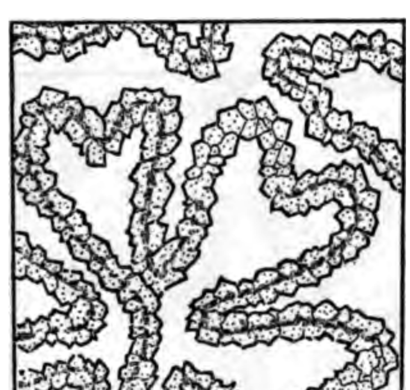


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

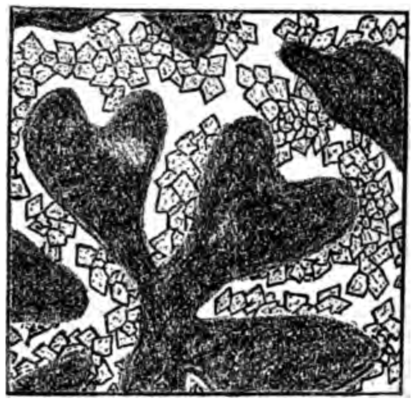


Fig. 66.—Coral substance replaced by porous mass of dolomite crystals; cavities filled with fine calcareous detritus dolomitised.

Fig. 67.—Coral substance converted into granular calcite; cavities containing water-clear calcite in some cases, and in others first a layer of transparent dolomite crystals, and then fibrous encrusting material consisting of alternating layers of calcite and dolomite.

Fig. 68.—Originally coral with cavities partly filled with fine calcareous detritus; coral substance removed by solution; cavities so formed, and those incompletely filled with calcareous detritus, lined with crystals of calcite, deposited from solution, the whole then dolomitised, and, lastly, fibrous encrusting calcite, deposited in certain of the empty spaces.

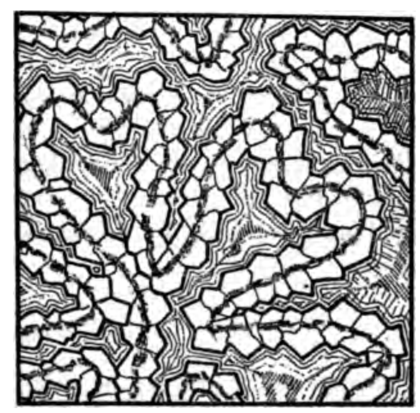


Fig. 69.—Originally coral with empty spaces; coral substance removed by solution; cavities so formed and the original cavities of the coral lined with calcite crystals; these converted into dolomite; and lastly remaining cavities filled with fibrous encrusting deposit of calcite.

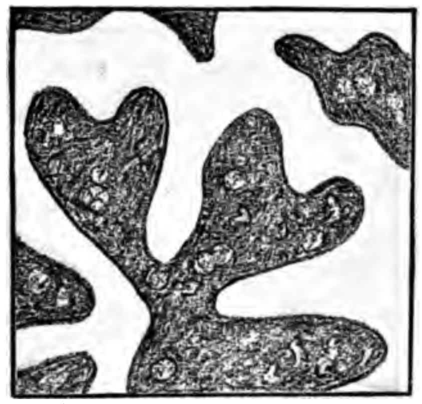


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

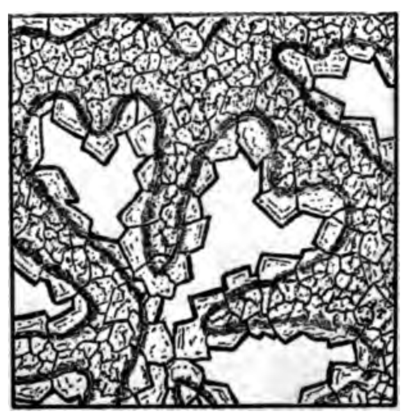


Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the recrystallised coral by a well-marked "dirt line."

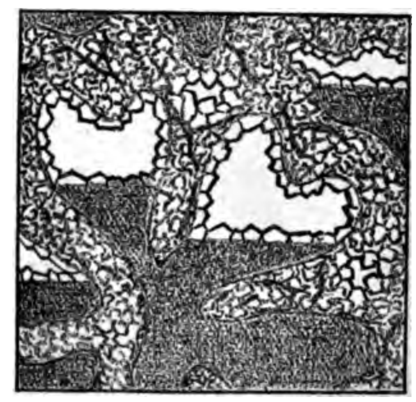


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

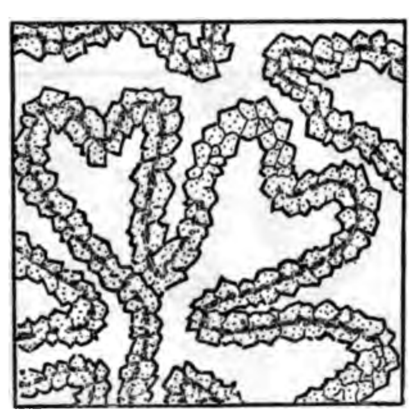


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

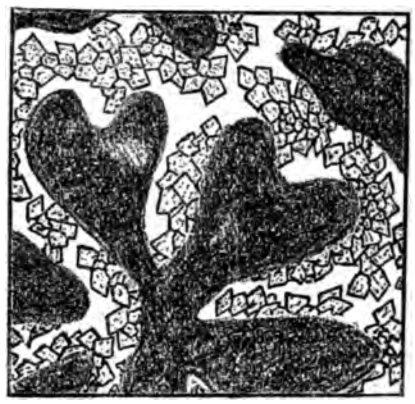


Fig. 66.—Coral substance replaced by porous mass of dolomite crystals; cavities filled with fine calcareous detritus dolomitised.

Fig. 67.—Coral substance converted into granular calcite; cavities containing water-clear calcite in some cases, and in others first a layer of transparent dolomite crystals, and then fibrous encrusting material consisting of alternating layers of calcite and dolomite.

Fig. 68.—Originally coral with cavities partly filled with fine calcareous detritus; coral substance removed by solution; cavities so formed, and those incompletely filled with calcareous detritus, lined with crystals of calcite, deposited from solution, the whole then dolomitised, and, lastly, fibrous encrusting calcite, deposited in certain of the empty spaces.

Fig. 69.—Originally coral with empty spaces; coral substance removed by solution; cavities so formed and the original cavities of the coral lined with calcite crystals; these converted into dolomite; and lastly remaining cavities filled with fibrous encrusting deposit of calcite.

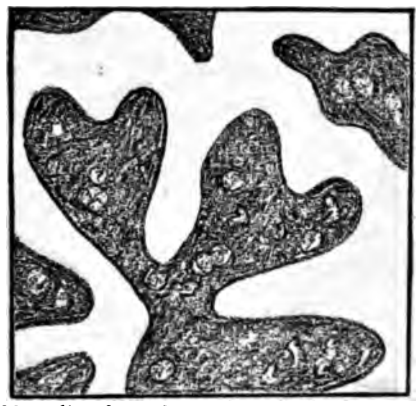


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the re-crystallised coral by a well-marked "dirt line."

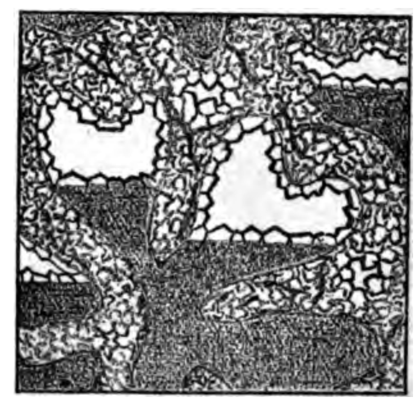


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

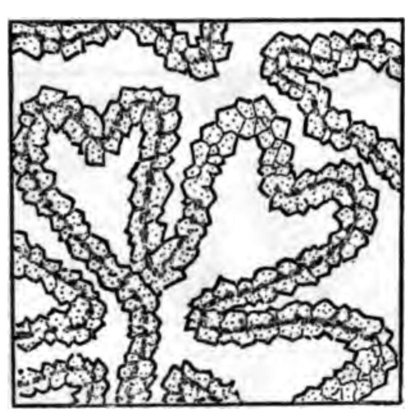


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

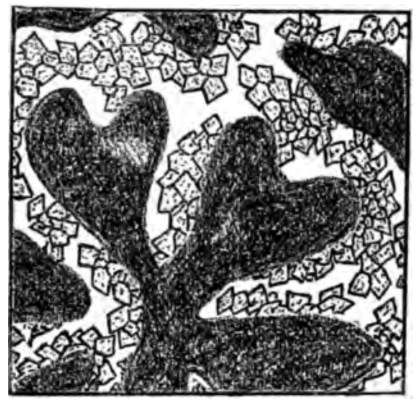


Fig. 66.— Coral substance replaced by porous mass of dolomite crystals; cavities filled with fine calcareous detritus dolomitised.

Fig. 67.—Coral substance converted into granular calcite; cavities containing water-clear calcite in some cases, and in others first a layer of transparent dolomite crystals, and then fibrous encrusting material consisting of alternating layers of calcite and dolomite.

Fig. 68.—Originally coral with cavities partly filled with fine calcareous detritus; coral substance removed by solution; cavities so formed, and those incompletely filled with calcareous detritus, lined with crystals of calcite, deposited from solution, the whole then dolomitised, and, lastly, fibrous encrusting calcite, deposited in certain of the empty spaces.

Fig. 69.—Originally coral with empty spaces; coral substance removed by solution; cavities so formed and the original cavities of the coral lined with calcite crystals; these converted into dolomite; and lastly remaining cavities filled with fibrous encrusting deposit of calcite.

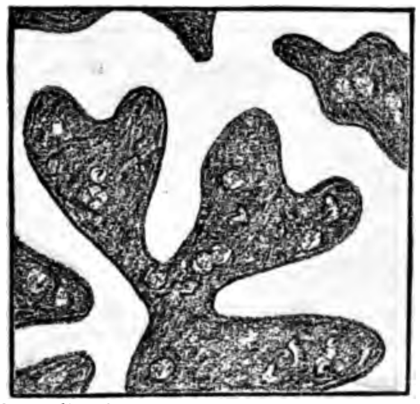


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the re-crystallised coral by a well-marked "dirt line."

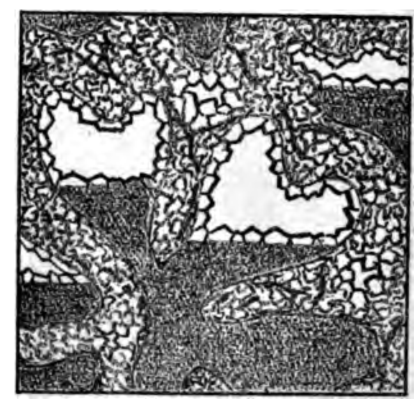


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

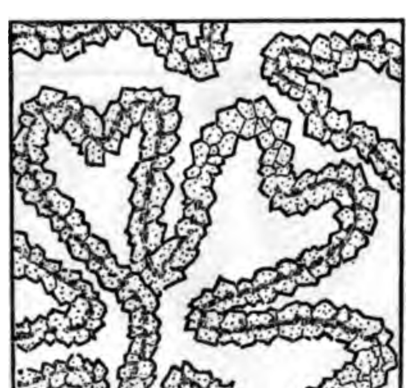


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

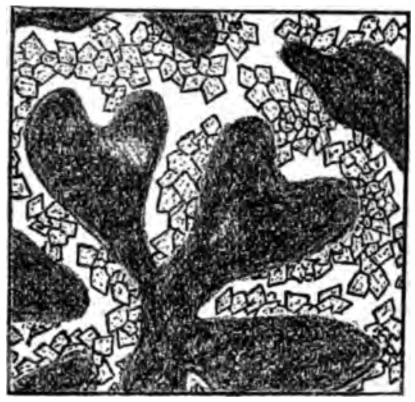


Fig. 66.—Coral substance replaced by porous mass of dolomite crystals; cavities filled with fine calcareous detritus dolomitised.

Fig. 67.—Coral substance converted into granular calcite; cavities containing water-clear calcite in some cases, and in others first a layer of transparent dolomite crystals, and then fibrous encrusting material consisting of alternating layers of calcite and dolomite.

Fig. 68.—Originally coral with cavities partly filled with fine calcareous detritus; coral substance removed by solution; cavities so formed, and those incompletely filled with calcareous detritus, lined with crystals of calcite, deposited from solution, the whole then dolomitised, and, lastly, fibrous encrusting calcite, deposited in certain of the empty spaces.

Fig. 69.—Originally coral with empty spaces; coral substance removed by solution; cavities so formed and the original cavities of the coral lined with calcite crystals; these converted into dolomite; and lastly remaining cavities filled with fibrous encrusting deposit of calcite.

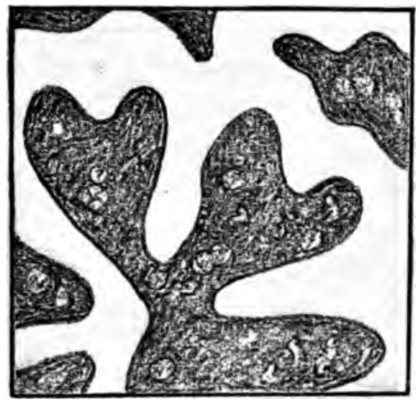


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the recrystallised coral by a well-marked "dirt line."

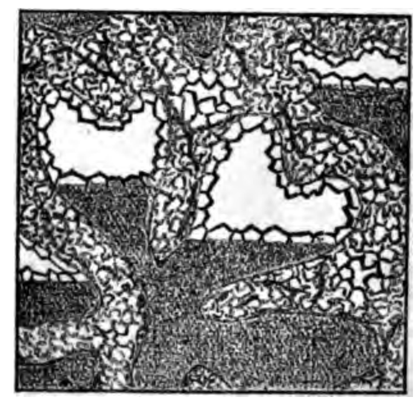


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

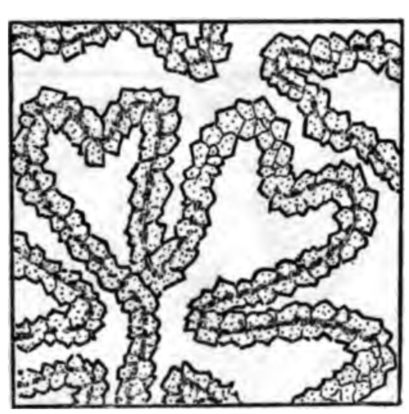


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

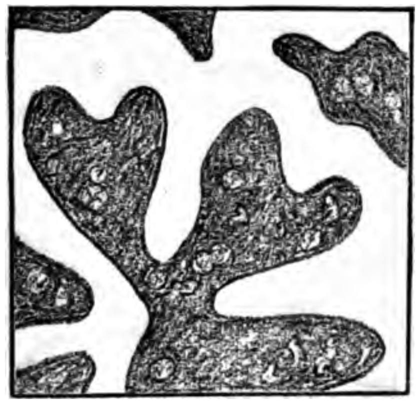


Fig. 60.—Coral substance entirely removed; cavities filled with calcareous detritus alone remaining (phenomenon of reversal).

Fig. 61.—Coral substance converted into porous mass of acute calcite crystals; cavities filled with fine calcareous detritus.

Fig. 62.—Coral substance converted into dolomite; cavities empty, except for a lining of clear dolomite crystals, separated from the re-crystallised coral by a well-marked "dirt line."

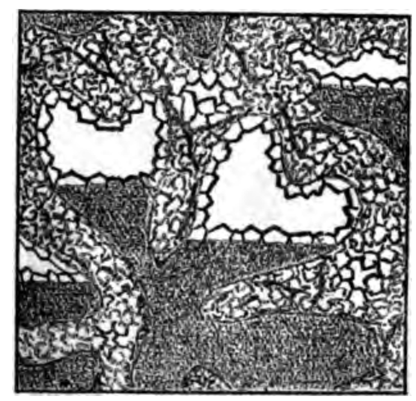


Fig. 63.—Coral-substance dolomite, traversed by "mud"-filled boring-tubes; cavities partly filled with dolomitised detritus, upper parts lined with clear dolomite crystals.

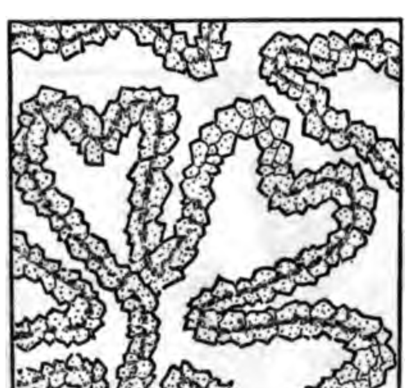


Fig. 64.—Coral substance removed by solution; cavities so formed, as well as the original cavities of the coral, lined with dolomite crystals, the two layers enclosing a fairly well-marked "dirt line" defining the original form of the coral.

Fig. 65.—Coral cavities filled with fine calcareous detritus; coral substance then removed by solution, cavities so formed afterwards filled by calcareous detritus ("secondary mud"), and finally the whole dolomitised.

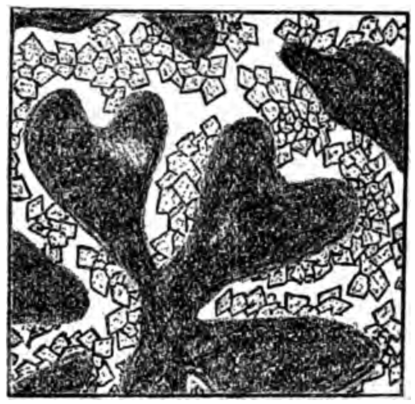


Fig. 66.—Coral substance replaced by porous mass of dolomite crystals; cavities filled with fine calcareous detritus dolomitised.

Fig. 67.—Coral substance converted into granular calcite; cavities containing water-clear calcite in some cases, and in others first a layer of transparent dolomite crystals, and then fibrous encrusting material consisting of alternating layers of calcite and dolomite.

Fig. 68.—Originally coral with cavities partly filled with fine calcareous detritus; coral substance removed by solution; cavities so formed, and those incompletely filled with calcareous detritus, lined with crystals of calcite, deposited from solution, the whole then dolomitised, and, lastly, fibrous encrusting calcite, deposited in certain of the empty spaces.

Fig. 69.—Originally coral with empty spaces; coral substance removed by solution; cavities so formed and the original cavities of the coral lined with calcite crystals; these converted into dolomite; and lastly remaining cavities filled with fibrous encrusting deposit of calcite.

DESCRIPTION OF PLATE F.

STAINED SECTIONS OF THE FUNAFUTI ROCKS.

(*Note.*—In figs. 1 and 2 the mineral which has taken the stain is aragonite, that which has remained unstained is calcite. In figs. 3, 4, 5 and 6 the coloured mineral is calcite, the uncoloured, dolomite.)

Fig. 1.—SOLLAS Boring No. 2. Core D. 9. Depth nearly 30 feet. × 100.

To the right is a mass of coral with encrusting organisms. To the left and below is a part of a *Halimeda* frond; separating this from the encrusted coral is finely-divided calcareous detritus ("primary mud"). Above is a large cavity lined with secondary calcite. The cavities inside the coral and *Halimeda* frond are nearly all filled with secondary aragonite; a few contain secondary calcite, which together with that in the cavity outside the organisms is of the fibrous encrusting type.

Fig. 2.—SOLLAS Boring No. 1. Core C. 20. Depth between 50 and 80 feet. × 100.

"Coral-reef sand" with constituent fragments cemented together by secondary calcite of the fibrous encrusting type.

Fig. 3.—Main Boring. Core 314 (lowest part). Depth 638 feet. × 200.

Partially dolomitised limestone. In some parts the organisms are seen to be coated with acute crystals of secondary calcite, which either project into empty spaces or are embedded in granular dolomite; in others these crystals have been dolomitised; and in still others the organisms themselves have suffered the change, with a resulting partial or complete obliteration. Some of the dolomite has possibly been deposited from solution, but the greater part is probably a substitute for pre-existing structures of calcite or aragonite.

Fig. 4.—Main Boring. Core 225 A. Depth 842 feet. × 200.

The organisms are coated with secondary calcite in acute crystals. These project into a layer of clear dolomite, the rhombohedral crystals of which are covered in turn by secondary calcite of the fibrous encrusting type.

Fig. 5.—Main Boring. Core 237 A. Depth 850 feet. × 100.

The untinted part of the section represents a portion of a large mass of dolomitised coral, the cavities in and around which are lined with a thick deposit of fibrous encrusting calcite.

Fig. 6.—Main Boring. Core 270 A. Depth 868 feet. × 200 (slightly diagrammatic).

The layer of clear and well-defined dolomite crystals rests upon and encloses a mass of coral, which has been converted into calcite. This layer in turn is covered up by a thick deposit having a radiating structure, and consisting of bands of calcite and films of dolomite in regular alternation.

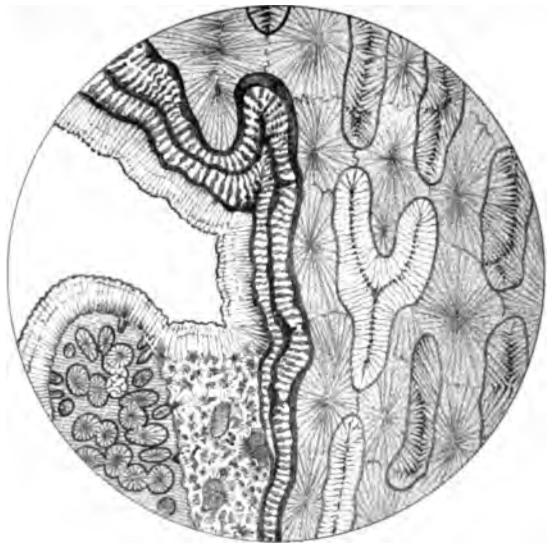


Fig. 1.

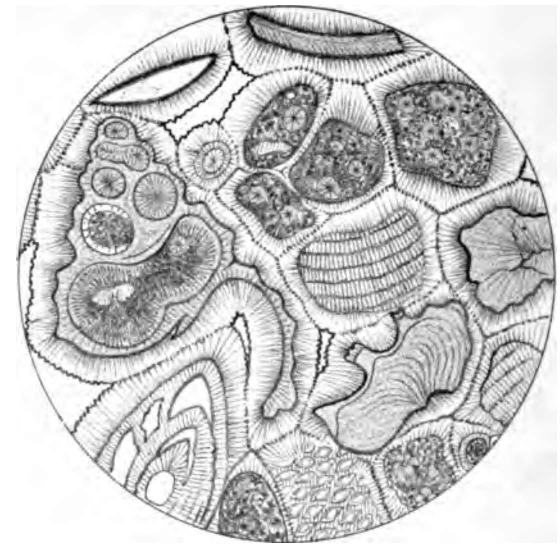


Fig. 2.

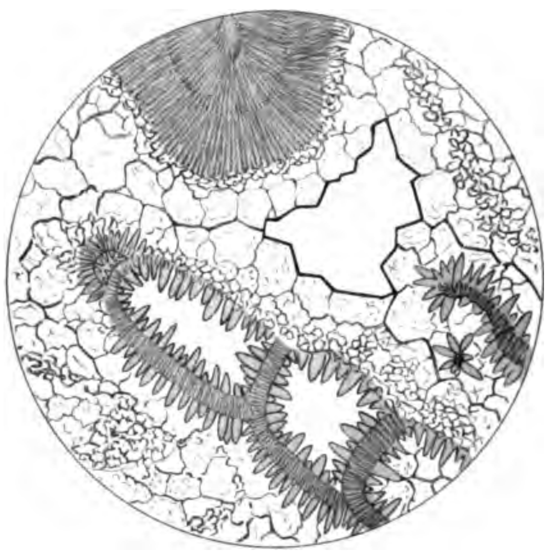


Fig. 3.

Fig. 4.

Fig. 5.

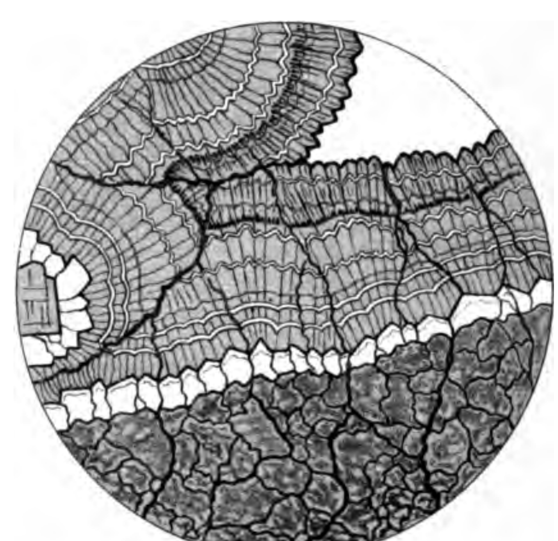


Fig. 6.

C. G. Cullis del. ad nat. West, Newman chromo.

INDEX.

HARRISON AND SONS, PRINTERS IN ORDINARY TO HIS MAJESTY, ST. MARTIN'S LANE.

r